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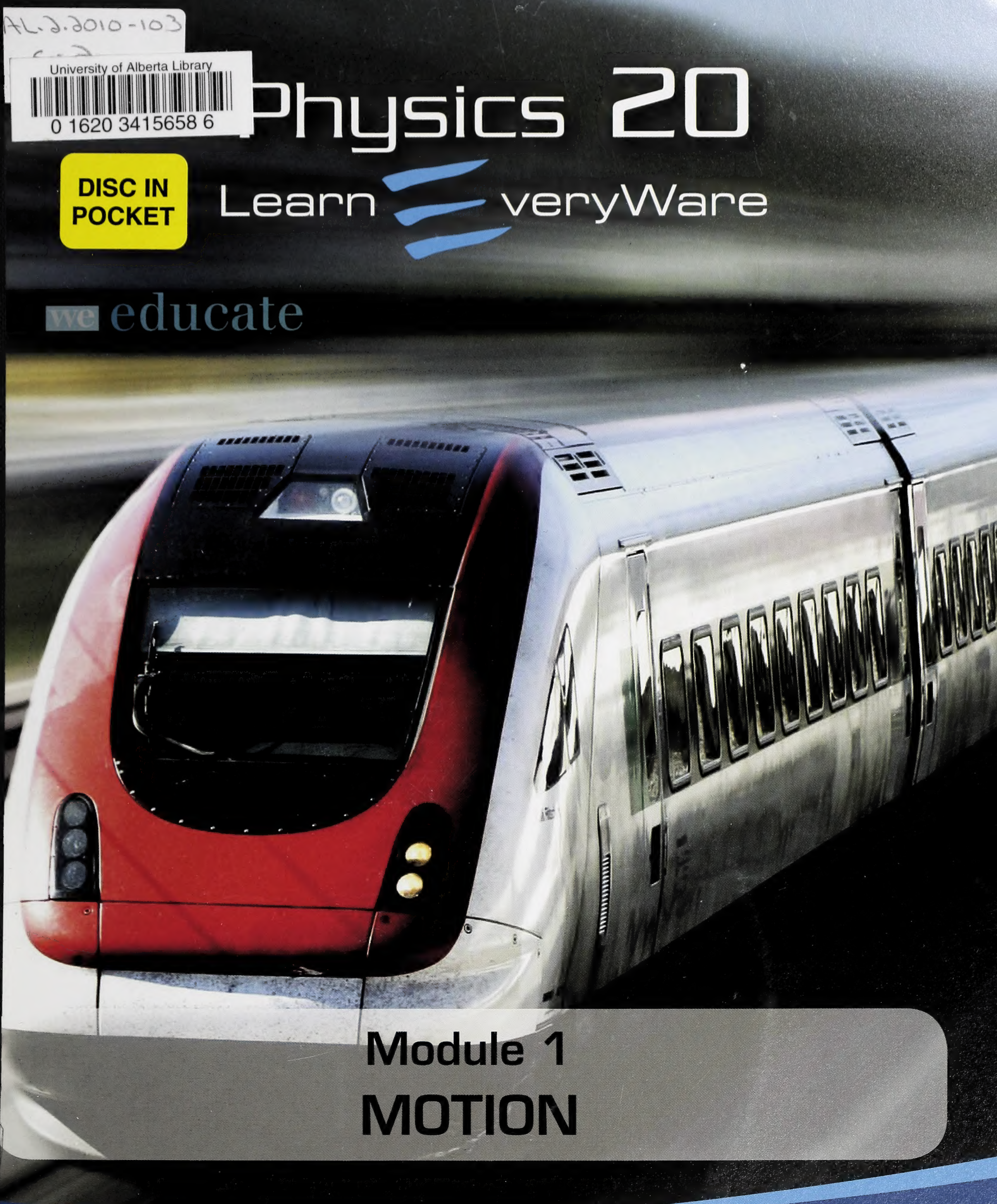

Physics 20

LearnEveryWare

we educate

Module 1
MOTION

Rocky View School Division
Red Deer Catholic Regional Schools
Pembina Hills Regional School Division No.7
Black Gold Regional Schools
Peace Wapiti School Division No.76
Calgary Board of Education
Edmonton Public Schools
Alberta Education


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Multimedia
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Education

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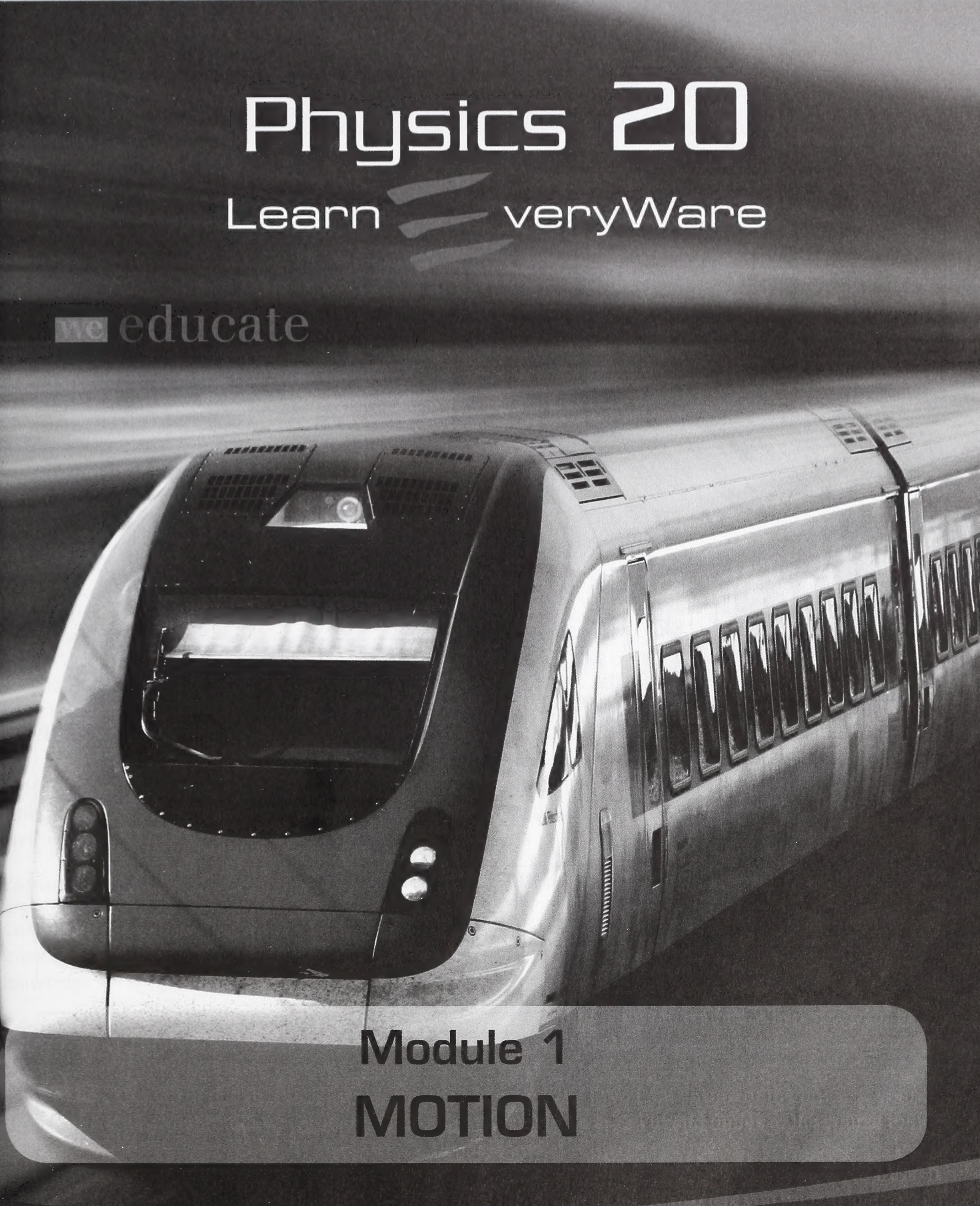

Module 1
MOTION

Red Deer Catholic Regional Schools

EDMONTON PUBLIC SCHOOLS

Calgary Board of Education

Alberta Education

Physics 20 was created by Alberta Education in partnership with the following educational jurisdictions under the terms of the *BCP Collaborative Course Development Project*:

- Black Gold Regional Schools
- Calgary Board of Education
- Edmonton School District No. 7
- Peace Wapiti School Division No. 76
- Pembina Hills Regional Division No. 7
- Red Deer Catholic Regional Division
- Rocky View School Division No. 41

Physics 20
Module 1: Motion
Student Module Booklet
ISBN 978-0-7741-3004-2

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This document is intended for	
Students	✓
Teachers	✓
Administrators	
Home Instructors	
General Public	
Other	

You may find the following Internet sites useful:

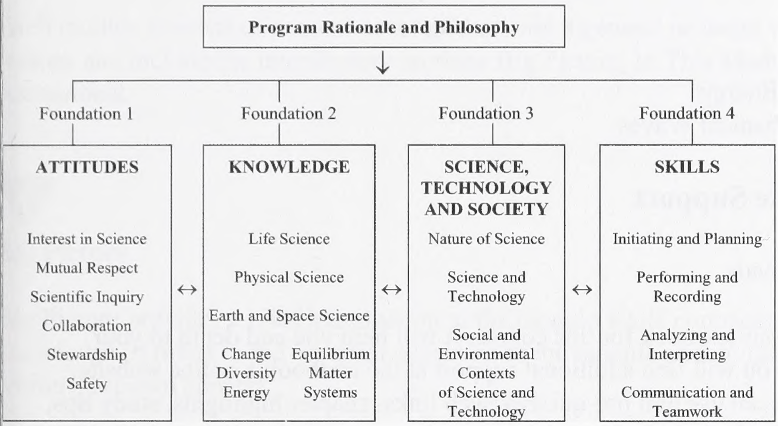
- Alberta Education, **http://www.education.gov.ab.ca**
- Learning Resources Centre, **http://www.lrc.education.gov.ab.ca**
- Tools4Teachers, **http://www.tools4teachers.ca**

Exploring the electronic information superhighway can be educational and entertaining. However, be aware that these computer networks are not censored. Students may unintentionally or purposely find articles on the Internet that may be offensive or inappropriate. As well, the sources of information are not always cited and the content may not be accurate. Therefore, students may wish to confirm facts with a second source.

Physics 20

Welcome to Physics 20

In Physics 20 you will learn more than facts. You will be encouraged to develop positive attitudes and to acquire and use knowledge and skills in responsible ways. Your studies will lead you to achievements in each of the following four areas prescribed by the Alberta Program of Studies.



Foundation 1

Attitudes—*Students will be encouraged to* develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Foundation 2

Knowledge—*Students will* construct knowledge and understandings of concepts in life science, physical science, and Earth and space science and apply these understandings to interpret, integrate, and extend their knowledge.

Foundation 3

Science, Technology, and Society (STS)—*Students will* develop an understanding of the nature of science and technology, the relationships between science and technology, and the social and environmental contexts of science and technology.

Foundation 4

Skills—*Students will* develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

This course builds upon the scientific concepts from

Grade 7 Science, Unit D: Structures and Forces
Grade 8 Science, Unit D: Mechanical Systems
Grade 9 Science, Unit E: Space Exploration
Science 10, Unit B: Energy Flow in Technological Systems

Physics 20 is composed of four units that prepare students for further study in the position and velocity of objects and systems, the concepts of fields and gravitational effects, circular motion, mechanical energy, work and power, simple harmonic motion, and mechanical waves. These units are

Unit A: Kinematics
Unit B: Dynamics
Unit C: Circular Motion, Work, and Energy
Unit D: Oscillatory Motion and Mechanical Waves

Physics 20 Textbook and Website Support

Pearson Physics, Pearson Education Canada

You will be using *Pearson Physics* as your textbook for this course. It will help you add depth to your understanding of the topics you study. You will find additional support at the textbook's online website, http://www.physicssource.ca. Here, you can use unit pre-quizzes, web links, chapter highlights, study tips, research tools, and other opportunities for further learning.

About Physics 20

The learning model used in Chemistry 20 is designed to be engaging and to have you participate in inquiry and problem solving. You will actively interpret and critically reflect on your learning process. Learning begins within a community setting at the centre of a larger process of teaching and learning. You will be encouraged to share your knowledge and experiences by interaction, feedback, debate, and negotiation.

Components

This Physics 20 course has three main components. It consists of eight Student Module Booklets, eight Assignment Booklets, and the Physics 20 Multimedia DVD.

Course Structure

The course uses the following structure to connect you to the relevant curriculum and scientific concepts in Physics 20. These components are used consistently throughout the course and will help you in seeing the context and overall content of the program.

Unit

The units of study are identified in the Program of Studies. Units are defined by subject matter and are not limited by quantity of content or time of study. Each unit is comprised of modules (usually one for each general outcome), includes a general introduction and a visual representation of content structure (e.g., concept organizer/site map) as well as a list of general outcomes to be addressed, and includes a unit summary and assessment.

Module

Each module consists of content developed around a general or major outcome. Modules are comprised of lessons and include the introductory sections Big Picture, In This Module, and Module Summary and Assessment.

Big Picture

Big Picture provides a brief introduction to the module while connecting to your prior learning and personal knowledge. It refers to the essential questions of the module and invites you to reflect on the "big picture" within your own context.

Discuss

Discuss provides opportunities for you to interact with your peers and teacher. Discussion topics and collaborative activities should be independent of delivery mode, given the variety of technology access and delivery methods in schools.

Explore

Explore encourages you to investigate new concepts through preparation and presentation (Read), multimedia interactions (Watch and Listen), hands-on simulations (Labs), and explorative activities (Try This). Components within this section often do not follow a specific order. For example, you can do Watch and Listen after Try This or do Labs before Read.

Get Focused

Get Focused encourages you to focus on the task at hand and the outcomes to achieve. It includes a list of knowledge outcomes, STS outcomes, and/or skills outcomes. It prepares you for the upcoming lesson by providing a lesson rubric, a list of assessment items, and a list of required equipment and materials.

Going Beyond

Going Beyond gives you the choice of challenging and enriching your knowledge beyond the lesson.

Lab

Labs include hands-on activities with available equipment/materials and/or multimedia simulations of a lab.

Lesson

Each lesson consists of the main learning content from which you explore, reflect, and connect. The length of each lesson is defined by content that covers at least one measurable outcome.

Read

The Read component uses textual material to convey concepts to you. This material may appear directly within this component. Alternatively, it may be presented indirectly through another resource. For example, you may be sent to your textbook or provided with a link to a website.

Reflect and Connect

Reflect and Connect provides you with opportunities to check your understanding of concepts introduced in the lesson (Self-Check) and to make connections to prior learning and personal knowledge (Reflect on the Big Picture). It also provides you with opportunities to interact with your peers and your teacher through communication and collaboration (Discuss).

Reflect on the Big Picture

Reflect on the Big Picture, part of Reflect and Connect, provides connections to the Big Picture introduced at the beginning of the module. It connects and adds to the initial essential question(s) and situates the concepts of the lesson within the Big Picture context.

Summary

There are course, unit, module, and lesson summaries. All lesson summaries build toward the unit and course summaries and make connections to the Big Picture introduced at the module level. Each summary provides you with information about what you have accomplished.

Self-Check

Self-Check provides you with opportunities to check your understanding of new concepts learned in the lessons and to make connections to prior learning. You may be able to check your own work, or you may require teacher feedback.

Try This

Try This includes opportunities to practise and apply learned concepts outside of a lab environment. These can be simulations, questions, webquests, or other activities that provide you with a space to explore different ways of applying new concepts.

Watch and Listen

Watch and Listen includes both passive and interactive multimedia content (podcasts, videos, interactive Flash activities, etc.).

Visual Cues (Icons)

You will see icons throughout the course. These icons are clues regarding the type of activity you are about to begin.

Each unit in the course has a different colour theme, and the icons will change colour to match. For example, here are the four different colours of the Big Picture icon that appear in Units A to D, respectively.


Unit A


Unit B


Unit C


Unit D

The icons and their meanings are given.


Big Picture


Assessment


Summary


Get Focused


Read


Try This


Self-Check


Reflect and Connect


Explore


Reflect on the Big Picture


Going Beyond


Watch and Listen


Discuss


Lab

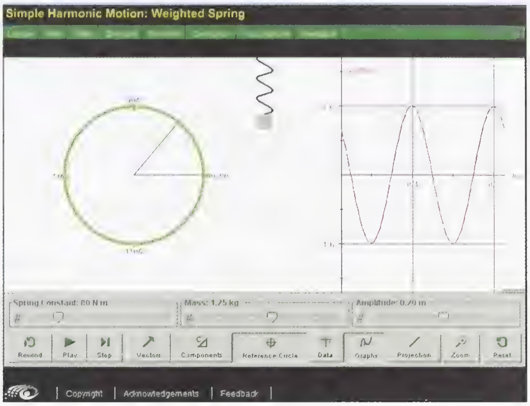
Reference (Data Tables)

In this course you will need numerical and scientific data for reference. Your textbook, *Pearson Physics*, has data tables in the appendix. For a list of standard equations, you should consult the Data Booklet for physics from Alberta Education. The Data Booklet also contains numerical and scientific data.

You will be allowed to use a copy of the Data Booklet when writing the Physics 30 Diploma Examination. That is a good reason for becoming familiar with the Data Booklet. The Data Booklet can be downloaded from http://www.education.alberta.ca/admin/testing/diplomaexams.aspx.

Special Learning Activities: Labs and Simulations

In Physics 20 you will use a large number of computer simulations to help you master concepts. You will often use the simulations to carry out activities that give you similar experiences to those in a lab. In some ways, simulations provide you with an enhanced lab experience because additional tools to analyze what is going on are available in the simulations.



The majority of the simulations can also be found at LearnAlberta.ca if your usual connection isn't working.

The simulations generally have a form similar to the sample shown above. You will be able to change parameters using sliders, choose which items show on the screen using buttons, access information about the simulation and how it works from menus at the top of the screen, and carry out and replay the actions.

Physics 20 was developed with simulations as a major component and requires you to use them regularly.

Glossary

A physics glossary—an alphabetical list of physics terms and their meanings—is provided in this course. Your textbook, *Pearson Physics*, also has a glossary for you to refer to.

Lesson Answers (for students)

For many items, answers are provided through a "Check your work" link. Some items, especially assessment items, are to be marked by your teacher. For these items, submit your work to your teacher.

Using the Physics 20 Course Folder

The Physics 20 course folder serves as the organized collection of your work in Physics 20. It exhibits to others your efforts, achievements, self-reflection, and progress throughout the course. When you want to show your friends or family what you've been learning, your work is all there.

You will be expected to put all of your work into the course folder. If you are unsure of the process, your teacher will walk you through it. Throughout the course you will be asked to add things to the course folder.

In addition to being able to show others what you have done, the course folder lets you see your progress. It lets you see how your knowledge, skills, and understandings are growing. It also lets you review and annotate work you have already completed. You may find your course folder useful in preparing for tests and quizzes.

Periodically, you will be asked to share items from your course folder with your teacher. This is not always for grading, as often your teacher may use these items to learn more about you and your interests or as a way of tailoring other work assigned to you.

Technical Requirements

This course requires the following technical requirements.

Minimum System Requirements:

PC Compatible

- Intel(R) Pentium(R) III or AMD-K6(R)-2 processor-based computer
- 450 MHz CPU
- Microsoft(R) Windows(R) 2000/XP
- 512 MB RAM
- monitor capable of 1024 x 768 screen resolution and 16-bit colour
- 16-bit sound card and speakers
- 1x DVD-ROM drive (for print version)
- A printer is recommended.

Macintosh(R)

- Power Macintosh(R) G3
- 500 MHz CPU
- Mac OS(R) X
- 512 MB RAM
- monitor capable of 1024 x 768 screen resolution and thousands of colours
- 16-bit sound card
- 1x DVD-ROM drive (for print version)
- A printer is recommended.

Minimum Software Requirements*:

For All Platforms

- Adobe(R) Reader(R) 6.0 (Download from http://www.adobe.com/downloads/)
- Adobe(R) Shockwave(R) Player 8.5 (Download from http://www.adobe.com/downloads/)
- Adobe(R) Flash(TM) Player 7 (Download from http://www.adobe.com/downloads/)
- Microsoft(R) Office Excel(R) 2003
- Microsoft(R) Office Word 2003 (optional)
- QuickTime(R) Player 7.0 (Download from http://www.apple.com/quicktime/download)

For Windows(R) 2000/XP

- Microsoft(R) Internet Explorer 6.0 for Windows(R) (Download from http://www.microsoft.com/windows/ie/ie6/downloads/default.mspx) OR
- Mozilla(R) Firefox(R) 2 (Download from http://www.mozilla.org/download.html)
- Java(TM) 2 Platform Standard Edition (J2SE 1.4.1) (Download from http://java.sun.com/javase/downloads/index.jsp)

For Mac OS(R) X

- Safari(TM) 1.3
- Java(TM) 2 Platform, Standard Edition, version 1.4.1 for Mac OS(R) X (Download from http://apple.com/java)

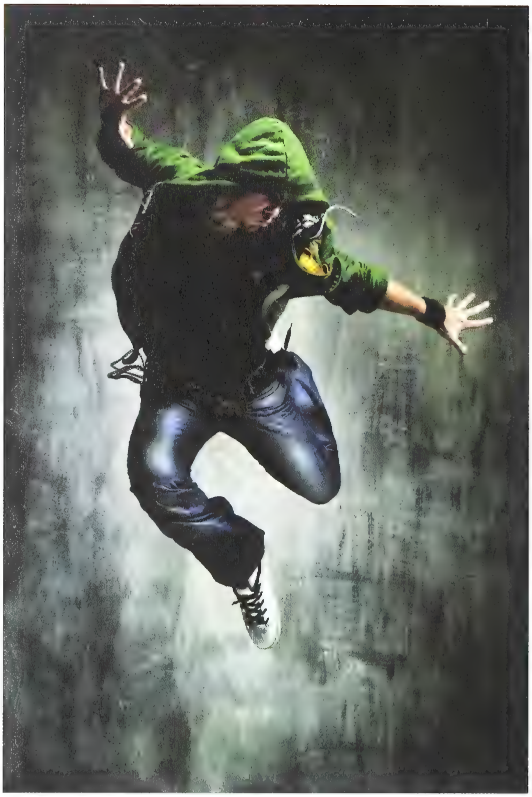
* Please note that vendors may have a more current version of their players and/or plug-ins available, which you can download from their sites, than the minimum software requirements listed above.

Contents

Module 1—Motion

Module Introduction

In this module you will develop the tools and the language to describe motion clearly, concisely, and in a format that physicists worldwide understand. The major new item you will focus on in Module 1 is the vector. You will see how vectors are used to describe motion. You will also see how graphs of motion-related entities can help solve real-world problems. Finally, you will begin to use new equations that will also help in solving problems.



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Big Picture

Have you ever been in a traffic jam waiting to inch ahead only to just wait some more? Did you wish you lived in an earlier age where high tech meant a carriage behind a horse? It was in such an age that the material discussed in this module was developed. It was developed from centuries of observation and attempts at understanding and predicting. Like the physicists of old, you will be looking at, describing, and analyzing moving objects.

© Carole Gomez/shutterstock

People move through the modern world using a variety of methods. Whether you are walking; paddling a canoe; or travelling in a chuckwagon, car, airplane, or rocket, your motion can be analyzed with physics. But is the motion experienced when using the methods described here the same? Does your speed and direction have an effect on your motion? How can you accurately and precisely describe your motion?

Many of the ideas about motion and movement will be familiar to you from junior high science courses and Science 10. Many of the mathematical tools will also be familiar to you from earlier mathematics courses. You will use simple trigonometry and other ideas about triangles that you first looked at in junior high.

In this module you will learn to describe moving objects. As you would expect, the language of physics uses specialized words and phrases. You will use the special language of kinematics to make the description unambiguous. You will also use other descriptive tools, such as graphs and tables, to see trends and patterns in how objects move.

Every day, you are involved in the science of kinematics, but you probably haven't used the language of kinematics to describe things that are in motion. While working on the lessons and labs, keep in mind that you are trying to describe something that seems very simple but that may be difficult to describe in a meaningful way.

As you are working in Module 1, you should keep the following questions in mind. They should help you fit the world of kinematics into your everyday world.

Essential questions for you to consider in this module are the following:

- What concepts are needed in describing motion?
- How are vectors and scalars used in describing motion?
- How are acceleration, velocity, and displacement used in describing motion?

In This Module

Lesson 1—The Language of Motion: Working with Vectors

In this lesson you will define and graphically represent a vector quantity, including magnitude and direction, using the Cartesian method and the navigational method of vector notation. You will also be able to calculate vector magnitude and direction based on Cartesian components and vice versa.

- How would you describe the direction a moving object takes?
- How would you represent the size of a quantity graphically?

Lesson 2—The Language of Motion: Working with Displacement, Velocity, and Acceleration Vectors

In this lesson and related lab activities you will determine the difference between scalar quantities (distance and speed) and vector quantities (displacement, velocity, and acceleration).

- Why is a distinction made between speed and velocity?
- How are acceleration, velocity, and displacement related?

Lesson 3—Graphical Analysis of Uniform Motion

In this lesson you will describe and compare one-dimensional, uniform motion using position-time and velocity-time graphs. There are five parts to the lesson:

- Part 1: Interpreting Position-Time Graphs for Motion in One Dimension
- Part 2: Determining Velocity Using a Position-Time Graph
- Part 3: Comparing Observed Motions with Position-Time Graphs
- Part 4: Interpreting Velocity-Time Graphs for Motion in One Dimension
- Part 5: Determining Displacement Using a Velocity-Time Graph

Why would a graph assist in describing motion? How do graphs of acceleration, velocity, and displacement build from each other?

Lesson 4—Graphical Analysis of Accelerated Motion

In this lesson and related lab activities you will describe and compare one-dimensional, accelerated motion using position-time, velocity-time, and acceleration-time graphs. Using slope and area calculations, you will be able to generate data and solve problems related to accelerated motion.

- How can you find the slope of a changing graph?
- How do graphs of acceleration, velocity, and displacement relate to each other?

Lesson 5—Kinematics Equations Describe Acceleration, Displacement, and Velocity

In this lesson you will investigate, derive, and apply kinematics equations to solve complex problems involving applications of constant acceleration.

- What mathematical tools can you use to solve moving-object problems?
- How can motion be put into equations?

Module Assessment

The assessment in this module consists of five (5) assignments, as well as a final module project.

- Module 1: Lesson 1 Assignment
- Module 1: Lesson 2 Assignment
- Module 1: Lesson 3 Assignment
- Module 1: Lesson 4 Assignment
- Module 1: Lesson 5 Assignment
- Module 1 Project

For the Module 1 Project, you will be required to submit the KWL chart and short paragraph you have been developing in Lessons 1 through 5. You will be given final instructions in the Module Summary. Look for instructions under the heading Module 1 Project.

This project will be graded out of 25 marks: 5 marks for each lesson. Each lesson's part of the KWL chart will be scored according to the following guidelines.

Score	Criteria
5 Excellent	The response includes statements covering all parts of the lesson fully using relevant facts and details. Statements made in the response are organized and unambiguous with only minor omissions.
4 Good	The response includes statements covering all parts of the lesson adequately. Statements made in the response are unambiguous and mostly complete.
3 Satisfactory	The response includes statements addressing the basic parts of the lesson. Statements made in the response may be disorganized, ambiguous, or incomplete.
2 Limited	The response includes some statements addressing some of the parts of the lesson. Statements made in the response lack details and clarity.
1 Poor	The response includes a few statements that address some parts of the lesson.
0 Insufficient	The response is incomplete and/or totally off topic.

The paragraph will be graded out of 3 marks.

Lesson 1—The Language of Motion: Working with Vectors

Get Focused

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Chuckwagon racing is a perfect example of a race in which the winner, assuming he or she completes the race, actually doesn't go anywhere—at the end of the race, the chuckwagon is in the same position as it was when the race began. So how fast did the horses run? The horses ran fairly fast considering the race is usually over in less than 1 minute and 20 seconds. What is really interesting, though, is that since the chuckwagon didn't really change position from start to finish, it actually maintained an average velocity of exactly 0.0 m/s. It seems strange to think of a moving object maintaining a fairly high rate of speed, yet still having an average velocity of zero at the end of the race. The explanation for this is that speed and distance are defined differently than the vector quantities velocity and displacement. In order to understand the difference between speed and velocity, you must first understand how a vector is defined.

In this lesson you will define and graphically represent vector quantities, including magnitude and **direction**, using the Cartesian method and the navigational method of vector notation. You will also be able to calculate vector magnitude and direction based on Cartesian components and vice versa.

direction: the course that an object follows

This first lesson may seem quite a challenge with all the new content presented. These new concepts will be important in supporting your work in the rest of the lessons in the module. The subsequent lessons will not challenge you with as much new content but will provide opportunities to practise and apply these concepts along with new ones you will learn.

In this lesson you will begin your Physics 20 course folder. You will need a container (either real or virtual) to hold the items that you produce. These items will provide you with a growing indicator of your progress through Physics 20 and will let you show your teacher and others how much your have learned.

In this lesson and related lab activities you will explore the following questions:

- What is a vector?
- How is a vector different than a number?
- How can you represent vectors?
- How can you communicate the direction of a vector?

Module 1: Lesson 1 Assignments

Your teacher-marked Lesson 1 Assignment requires you to submit a response to the following:

- Try This—TR 4, TR 6, TR 11, TR 12, TR 13, TR 14, TR 15, and TR 16
- Discuss

The other questions in this lesson are not marked by the teacher; however, you should still answer these questions. The Self-Check and Try This questions are placed in this lesson to help you review important information and build key concepts that may be applied in future lessons.

After a discussion with your teacher, you must decide what to do with the questions that are not part of your assignment. For example, you may decide to submit to your teacher the responses to Try This questions that are not marked. You should record the answers to all the questions in this lesson and place those answers in your course folder.

Explore

In a chuckwagon race, or in any race for that matter, the participants' location on the track is measured with respect to the starting line, which is known as the reference point or origin. The length of the path travelled by each chuckwagon is called the **distance**. To fully describe exactly where a chuckwagon is on the course, you need to give more than just a value for its distance.

One approach is to give the direction from a reference point or origin along with the distance. If you said that a chuckwagon is 25 m west of the finish line, then you would be describing its **position,** abbreviated as $\vec{d} = 25\,\text{m}\ [\text{W}]$.

If a chuckwagon was able to move from 25 m west of the finish line to 5 m west of the finish, then its position has changed—the chuckwagon is 20 m farther east than it was before. This change in position, of 20 m east, is called **displacement**.

Both position and displacement have a size or a magnitude—measured in metres—and a direction. This is why position and displacement are each an example of a **vector quantity**.

distance: the length of the path taken to move from one place to another

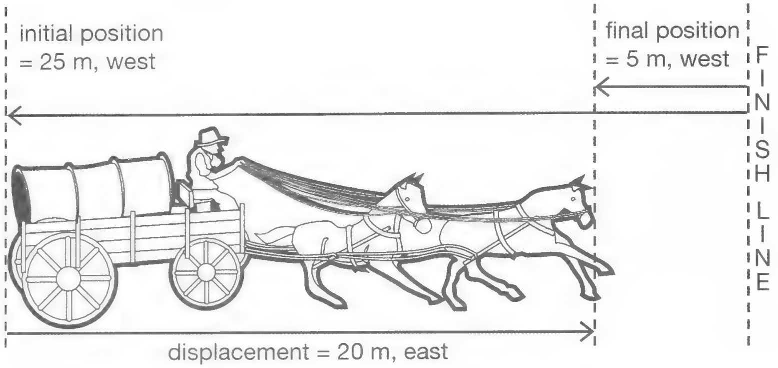
position: the straight-line distance and direction of an object from the origin

displacement: a change in position including both magnitude and direction

Distance is not a vector because it has no direction associated with it, so it is called a **scalar quantity**.

vector quantity: a measurement that has a magnitude and a direction

scalar quantity: a measurement that has only magnitude



Read

To learn more about displacement and position and how to work with these vector quantities, read "Physics Terms" and "Sign Conventions" on pages 6 to 10 of your textbook.

Self-Check

SC 1. The start of a chuckwagon race was captured on digital video by a friend of one of the competitors. The video revealed that just 8.5 seconds (s) into the race, the competitor had already moved to a location 12 m [W] of the start and that by 10.0 s this same competitor had moved to a spot 20 m [W] of the start. This information was analyzed by the competitor after the race to improve performance.

a. Determine which of the four measurements in the description of the video are vector quantities and which are scalar quantities. Support your answers.

b. Determine the displacement of the chuckwagon from 8.5 s to 10.0 s.

c. Use a sign convention to complete a calculation that verifies your answer to to SC 1.b.

SC 2. A digital video recording of a chuckwagon race was used to determine that a chuckwagon was moving at 9.0 m/s at one point in the race. Later footage helped establish that the winner crossed the finish line moving at 12.5 m/s [W].

a. Determine which of the two measurements in the description of the video is a vector quantity and which is a scalar quantity. Support your answers.

b. Use the proper physics variables to describe each of these measurements.

Check your work with the answer in the appendix.

Describing Directions

sign convention: a system for designating directions along a straight line; one direction is positive and the other is negative

The magnitude of a vector is expressed as a value with a unit. For example, the magnitude of a displacement vector could be expressed in metres, as in 5.6 m. When it comes to communicating the direction of a vector, there are a number of options. If the motion occurs along a straight line, which has only two possible directions, it is convenient to describe one direction as positive and the other as being negative. This arrangement is called a **sign convention**. Using a sign convention, east could be called the positive direction and west could be called the negative direction.

In most situations, motion happens in more than the two directions of the first example, so a sign convention is not adequate. The horses in the photograph are rounding a turn, switching from moving south to east and, in the process, momentarily going at each of the directions between south and east. When compass bearings (north, south, east, west, and all the directions in between) are used to describe this sort of motion, it is called the **navigator method**. At other times, it's more convenient to use an x-axis and a y-axis or the **Cartesian method**.

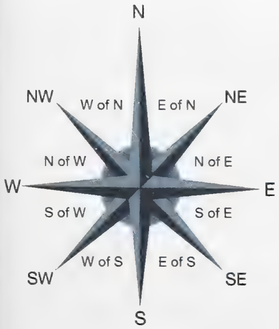
© Jack Dagley/Dreamstime

navigator method: a system for measuring directions using compass bearings

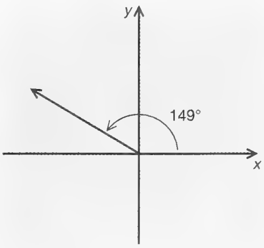
Cartesian method: a system for measuring directions using the x-axis and y-axis

Read

You can find out more about these two systems for describing directions by reading pages 76 to 78 in your textbook. Note how the units are included in the descriptions.



This illustration shows the navigator method.



This illustration shows the Cartesian method.

Self-Check

SC 3. The illustration on the right shows a position vector pointing at 149° using the Cartesian method. Describe this same direction in two different ways using the navigator method.

Check your work with the answer in the appendix.

Try This

You can learn more about the navigator method and the Cartesian method by using a computer simulation. This simulation is a great way to explore the use of angles to describe vector directions. Note that the simulation uses slightly different terminology and further subdivides the Cartesian method into three additional categories. You will not need to know all the categories for this course, but it is an opportunity for you to extend your understanding if you wish.

System Used in the Textbook	System Used in the Simulation
navigator method	navigator method
Cartesian method	polar (positive): measuring angles counterclockwise from the x-axis
	polar (positive & negative): measuring angles counterclockwise or clockwise from the x-axis
	x and y coordinates: describing directions in terms of x and y components

If you keep in mind that the last three methods used in the simulation are actually just variations of the Cartesian method, you should be able to keep it all straight. Also keep in mind that velocity values are normally always stated with units. An exception is made in this case since this simulation cannot accommodate units, so the units are not shown here. In this situation, assume that the magnitude is measured in m/s.

Go to **www.learnalberta.ca**. You may be required to input a username and password. Contact your teacher for this information. In the search bar, type the keywords "vector specification." Choose the item called "Vector Specification" from the list. Begin with Method 1.

Method 1: Cartesian Method (Polar Positive)

TR 1. On the control panel of the simulation, select the "Polar (positive)" mode and enter 150 for the magnitude and 240 for the angle. Press "Enter." Verify that the display matches Figure 1.

In this mode, an angle is measured from a reference line (shown dotted and pointing east) in the positive, counterclockwise direction that is indicated by the arc. Angles can range from 0° to 360°.

Note: 360° is equivalent to 0°.

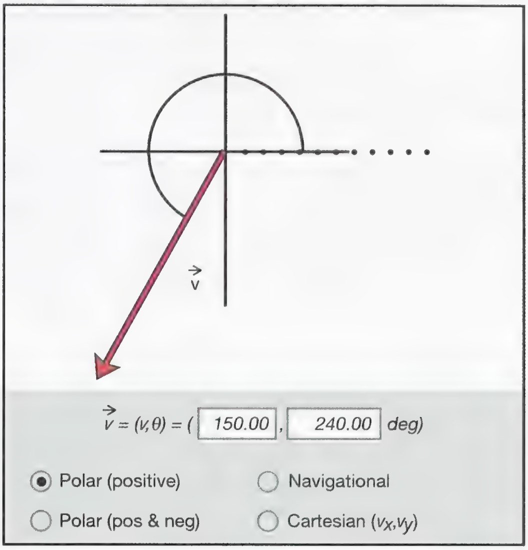


Figure 1

Method 2: Cartesian Method (Polar Positive & Negative)

TR 2. On the control panel of the simulation, select the "Polar (pos & neg)" mode without changing any of the settings from TR 1. Verify that the display matches Figure 2.

In this mode, both positive and negative angles are used. Vectors pointing above the horizontal reference line are assigned positive values between 0° and +180°. Vectors pointing below the horizontal reference line are assigned negative values between 0° and –180°.

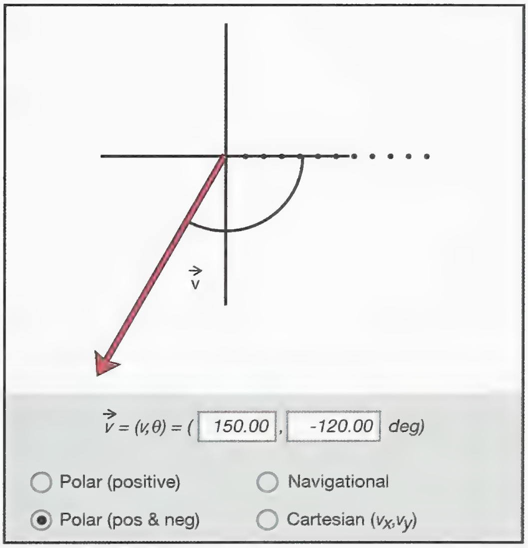


Figure 2

TR 3. Using the simulation on the "Polar (positive)" mode, set a vector that points into the first quadrant. (Pick a magnitude, and then enter an angle under 90°.) Change the setting to "Polar (pos & neg)," and look at the angle. Repeat this procedure for vectors in the second, third, and fourth quadrants. What is the largest possible angle for the "Polar (pos & neg)" system of coordinates?

Module 1: Lesson 1 Assignment

Remember to submit the answer to TR 4 to your teacher as part of your Lesson 1 Assignment in the Module 1 Assignment Booklet.

TR 4. Use the applet in the "Polar (positive)" mode and set a vector pointing into the first quadrant. Draw and label the vector magnitude and angle in the following table. Draw the same vector in the "Polar (pos & neg)" row of the table. Predict and label the angle in the "Polar (pos & neg)" mode. Repeat this procedure for vectors in the second, third, and fourth quadrants. Verify your answers using the applet.

Polar (positive) Specification	Polar (pos & neg) Specification
Quadrant 1 2 1 3 4 angle: ________	Quadrant 1 2 1 3 4 angle: ________
Quadrant 2 2 1 3 4 angle: ________	Quadrant 2 2 1 3 4 angle: ________
Quadrant 3 2 1 3 4 angle: ________	Quadrant 3 2 1 3 4 angle: ________
Quadrant 4 2 1 3 4 angle: ________	Quadrant 4 2 1 3 4 angle: ________

Method 3: Navigator Method

TR 5. On the control panel of the simulation, select the "Polar (positive)" mode in the control panel of the simulation; enter 150 for the magnitude and 240 for the angle. Then select the "Navigational" mode, and choose "S of W" (South of West) from among the eight compass directions in the drop-down menu. Verify that the display matches Figure 3.

"South of West" means that the angle is measured starting from the west direction and then swinging south down towards the position of the vector.

Note: The three compass labels have been added to Figure 3 for your reference; they will not appear on the simulation display.

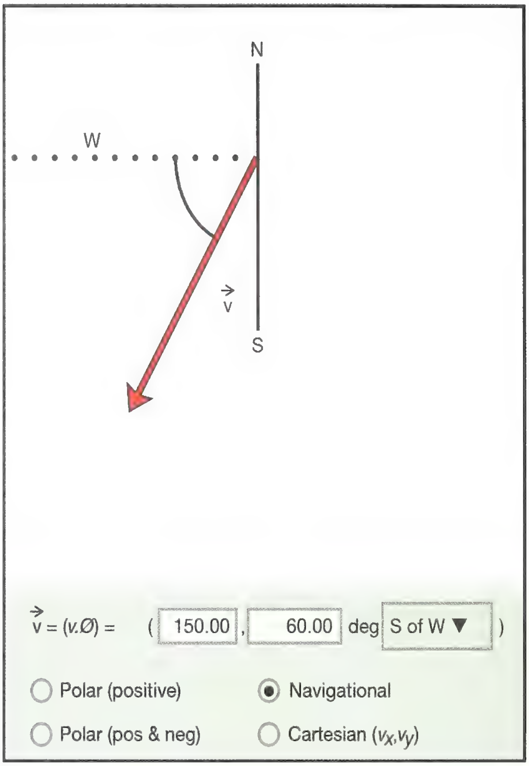
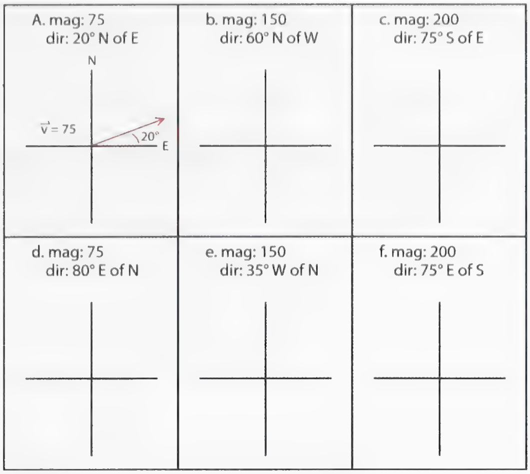


Figure 3

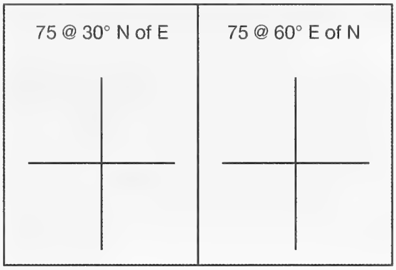
Module 1: Lesson 1 Assignment

Remember to submit the answer to TR 6 to your teacher as part of your Lesson 1 Assignment in the Module 1 Assignment Booklet.

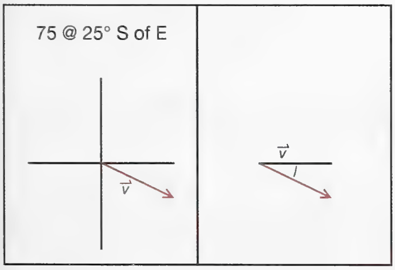
TR 6. Complete the following table by sketching the vectors and labelling the magnitude and direction. (Right-click on the table, and select Print Picture to obtain a paper copy of the table.) The first one has been completed as an example. Use the applet to verify your answers. To position the vector, put your cursor on the very tip of the vector arrow, and when a crosshair appears, click, hold, and drag the tip to wherever you wish.

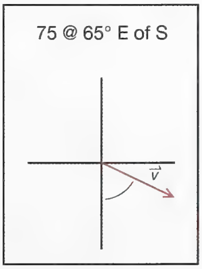


TR 7. Is there more than one way to specify the same navigational direction? Answer this by sketching the following two vectors and labelling the magnitude and direction. Use the applet to verify your answer.



TR 8. What is another way of indicating 75 @ 25°S of E using an angle less than 90°? Draw and label the vector below. Use the applet to verify your answer.





Method 4: Cartesian Method (*x* and *y* Components)

The fourth way to define a vector direction is fundamentally different than the three methods you have explored so far. In each of the previous methods, the magnitude and direction of the vector are described by two separate bits of information—one value for the magnitude and another for the direction (in one of three possible specifications). The fourth method uses *x* and *y* components on a Cartesian system to describe both the magnitude and direction of a vector.

Watch and Listen

Watch an animation to see how the direction of a vector can be indicated in different ways. Go to your Physics 20 Multimedia DVD, and choose the segment called "Cartesian Vector Components." This simulation will summarize previously studied methods and introduce the Cartesian method (x and y components) of vector specification.

Try This

You can learn more about the how x and y components are just another version of the navigator method and the Cartesian method using the Vector Specification computer simulation previously encountered. Note that the simulation uses slightly different terminology, and this application further subdivides the Cartesian method into three additional categories. However, the simulation is a great way to explore the use of angles to describe vector directions.

Re-open the "Vector Specification" simulation from **www.learnalberta.ca**.

TR 9. On the control panel of the simulation, select the "Polar (positive)" mode in the control panel of the simulation, and enter 150 for the magnitude and 240 for the angle. Then select the "Cartesian (v_x, v_y)" mode on the control panel. Verify that the display matches Figure 4, except for the numbers at the tip of the vector, which will not be present in the display.

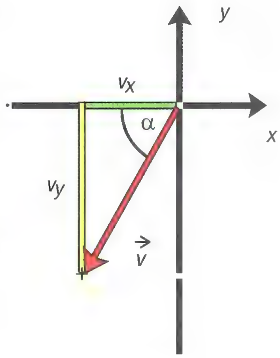


Figure 4

The projections of the vector onto the x- and y-axes, shown in green and yellow, respectively, are called the scalar components of the vector. They are called scalar components because they are numbers. The scalar components are equal to the x and y coordinates of the tip of the vector if the tail end of the vector is at the origin of the coordinate system, as it is here. The coordinates have been added to the display in Figure 4.

The x and y scalar components of a vector, $\vec{v}$, are denoted v_x and v_y, respectively. In the present case, this pair of components has the value $(v_x, v_y) = (-75.00, -129.90)$.

You can use the notation (v_x, v_y) to denote the vector $\vec{v}$, because the vector is fully specified in terms of its two scalar components. Thus, when required to calculate a vector, $\vec{v}$, you can give the final answer in the form above. There is no need to calculate the magnitude and direction of the vector because the components contain this information.

You could state your final answer in the form, $\vec{v} = (-75.00,\ -129.90)$.

However, when describing a vector by its two components, it must be understood from the context how the x- and y-axes are defined. In this case, the axes are defined as number lines with positive and negative directions.

Example 1

Given the magnitude and direction of a vector, how are the components (v_x, v_y) calculated?

First, make a diagram showing the relevant quantities, as shown in Figure 5.

The diagram shows a right-angle triangle containing the vector, $\vec{v}$, as the hypotenuse, with the other two sides equal to v_x and v_y, or rather, equal to their magnitudes $|v_x|$ and $|v_y|$ (since v_x and v_y are both negative in the present case). The angle, represented here by the Greek letter alpha (α), defines the orientation of $\vec{v}$. In order to apply trigonometric functions to solve for the components, you need to know this angle.

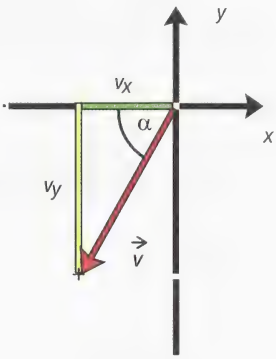


Figure 5

TR 10. Find this angle using the simulation. On the control panel of the simulation, select the "Polar (positive)" mode, and enter 150.00 for the magnitude and 240.00 for the angle. Then select the "Navigational" mode and "S of W" from the drop-down menu on the control panel.

$\alpha =$ __________

Knowing angle α allows you to use basic trigonometry to solve for the vertical component, v_y.

$$\sin\alpha = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\sin\alpha = \frac{v_y}{v}$$

$$v_y = (\sin\alpha)(v)$$

$$v_y = (\sin 60.00°)(150.00\ \text{m/s})$$

$$v_y = 129.9038106\ \text{m/s}$$

$$v_y = 129.90\ \text{m/s}$$

Figure 5 shows that v_y is downward and, therefore, negative.

$v_y = -129.90$ m/s

Basic trigonometry is also used to solve for the horizontal component, v_x:

$$\cos\alpha = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\cos\alpha = \frac{v_x}{v}$$

$$v_x = (\cos\alpha)(v)$$

$$v_x = (\cos 60.00°)(150.00\ \text{m/s})$$

$$v_x = 75.000\ \text{m/s}$$

Figure 5 shows that v_x is directed towards the left and is, therefore, negative.

$v_x = -75.000$ m/s

The vector components are correctly written as (–75.000 m/s, –129.90 m/s).

Again, remember units are normally always included in calculations. Units are not shown here because the simulation cannot accommodate them.

Example 2

Given scalar components v_x and v_y, how are the magnitude and direction of a vector, $\vec{v}$, calculated?

Applying the Pythagorean theorem ($c^2 = a^2 + b^2$) to the right-angle triangle in Figure 5 gives $v = 150.0$.

$$
\begin{aligned}
c^2 &= a^2 + b^2 \\
v^2 &= v_x^{\,2} + v_y^{\,2} \\
v &= \sqrt{v_x^{\,2} + v_y^{\,2}} \\
v &= \sqrt{(75.000\ \text{m/s})^2 + (129.90\ \text{m/s})^2} \\
v &= 149.9967\ \text{m/s} \\
v &= 150.00\ \text{m/s}
\end{aligned}
$$

Applying the definition of the tangent to the right-angle triangle in Figure 5 gives $\alpha = 60.00°$.

$$\tan\alpha = \frac{\text{opposite}}{\text{adjacent}}$$

$$\tan\alpha = \frac{v_y}{v_x}$$

$$\alpha = \tan^{-1}\left(\frac{v_y}{v_x}\right)$$

$$\alpha = \tan^{-1}\left(\frac{129.90\ \text{m/s}}{75.00\ \text{m/s}}\right)$$

$$\alpha = 60.0°$$

Combining the magnitude and angle gives the value of the vector:

$\vec{v}$ = 150.00 m/s [60.0° S of W]

or

$\vec{v}$ = 150.0 m/s [30.0° W of S]

Simulation Summary

While working with the simulation, you found that the direction of a vector can be specified in a number of different ways. You can use

- the Cartesian method:
    - positive angles measured from the positive x-axis in a counterclockwise direction—for example, 32.1 m/s [327°]
    - negative angles measured from the positive x-axis in a clockwise direction—for example, 27.8 m/s [–123°]
    - direction implicitly contained in the x and y components
- the navigator method:
    - measure direction with compass bearings—for example, 1.7 m/s [38° E of N]

Read

To learn more about determining vector components, read pages 83 to 84 of your textbook. Pay special attention to the use of units, particularly in "Example Problem 2.4" on page 84.

Self-Check

SC 4. The vector, $\vec{v}$, has the following components: $v_x = –75.0$ m/s, $vy = +200$ m/s. Calculate the magnitude and polar positive direction of the vector, $\vec{v}$. Show your work, and check your solution by setting it up in the simulation.

SC 5. Given the vector 126 m/s [65.0° N of E], calculate the x and y components. Show your work, and check your solution by setting it up in the simulation.

Check your work with the answer in the appendix.

Module 1: Lesson 1 Assignment

Remember to submit the answers to TR 11 and TR 12 to your teacher as part of your Lesson 1 Assignment in your Module 1 Assignment Booklet.

Try This

TR 11. The vector, $\vec{v}$, has the following components: $v_x = +65.0$ m/s, $vy = -120$ m/s

Calculate the magnitude and polar positive direction of the vector, $\vec{v}$. Show your work, and check your solution by setting it up in the simulation.

TR 12. Given the vector 225 m/s [35.0°W of S], calculate the x and y components. Show your work, and check your solution by setting it up in the simulation.

Module 1: Lesson 1 Assignment

Remember to submit the answers to TR 13, TR 14, TR 15, and TR 16 to your teacher as part of your Lesson 1 Assignment in the Module 1 Assignment Booklet.

Reflect and Connect

Online mapping services can be used to produce detailed directions for getting from one location to another.

Try This

TR 13. Working in a group or by yourself, generate and print a map showing how to go from your house to another location, such as your school or work. The other location must be at least one kilometre away and require more than two changes in direction.

TR 14. On the map, draw the vector that shows the displacement from your house to the other location (straight line).

TR 15. How can the magnitude and direction of this vector be determined using your map? Define the magnitude and direction using the Cartesian and navigational methods.

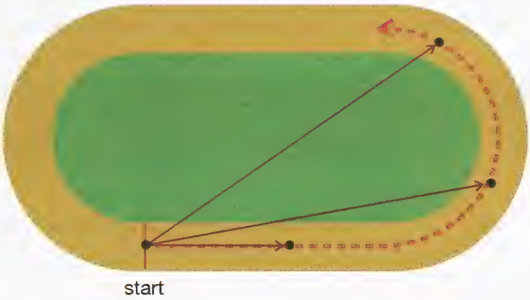
TR 16. Post your map to the discussion area, and view other maps. How did the straight-line displacement value (the "as the crow flies" version) compare to the distance value (path length) for your route?

Module 1: Lesson 1 Assignment

Remember to submit the answer to Discuss to your teacher as part of your Lesson 1 Assignment in the Module 1 Assignment Booklet.

Discuss

Average velocity is determined by dividing displacement by time. Position in a chuckwagon race can be illustrated with a vector arrow drawn from the starting point to the current location. The following diagram illustrates several position vectors drawn at different times in the race.



Use this diagram to explain why the displacement becomes zero just as the chuckwagon crosses the finish line and why the chuckwagon has an average velocity of zero when it reaches the finish line. Submit a copy of your response to your instructor, and store a copy in your course folder.

Reflect on the Big Picture

In this lesson a number of important concepts have been discussed and worked with. You saw how the mathematics of vectors and scalars can help you describe where objects are and how they move. You worked with different ways of describing the direction of an object's motion. You discovered the non-intuitive idea that average velocity can be zero even if you are travelling very quickly. In working with these ideas, you have started to build a solid base for the rest of this module.

Reflection is an activity that tries to culminate your learning experience by pondering who, what, when, where, and why about the activities you have completed. For this lesson, complete at least one of the following three activities and the KWL chart to help you reflect on your learning.

- Create a poem that connects the concepts and terms you learned with the descriptive language used in poetry.

- Create a drawing or painting that expresses the concepts of direction, motion, vector, and scalar. Add a small description to explain to others what the artwork is describing.

- Build a summary of the concepts and terms. Ensure that it describes in your words how the items relate to description of motion.

Store your completed reflection in your Physics 20 course folder.

Module 1: Lesson 1 Assignment

Ensure that you have completed all of the questions in the Lesson 1 Assignment. Contact your teacher to find out if you should submit your assignment now or wait until you have completed the Module 1 Assignment Booklet.

KWL Chart

For your Module 1 Project, you will complete a KWL chart like the following with your thoughts about the concepts from this lesson. Store your KWL chart in the Physics 20 course folder. You will be expected to add to it in each lesson and submit the total chart to your teacher for grading once you have completed Module 1.

K What I Knew	W What I Want to know	L What I Learned

Lesson Summary

In this lesson and related lab activities you explored the following questions:

- What is a vector?
- How is a vector different than a number?
- How can you represent vectors?
- How can you communicate the direction of a vector?

A vector quantity is a measurement that has both magnitude and direction. Direction is the essential characteristic of a vector quantity that makes it different from a number. Vector quantities (such as position, displacement, and velocity) can be graphically represented using an arrow. The length of the arrow represents the magnitude (amount) of the quantity. The direction of the vector can be described using a sign convention if the vector lies along a single straight line. If the vector is not restricted to a straight line, then the navigator method or the Cartesian method could be used.

Lesson Glossary

Cartesian method: a system for measuring directions using the x-axis and y-axis

direction: the course that an object follows

displacement: a change in position including both magnitude and direction

distance: the length of the path taken to move from one place to another

navigator method: a system for measuring directions using compass bearings

position: the straight-line distance and direction of an object from the origin

scalar quantity: a measurement that has only magnitude

sign convention: a system for designating directions along a straight line; one direction is positive and the other is negative

vector quantity: a measurement that has a magnitude and a direction

Lesson 2—The Language of Motion: Working with Displacement, Velocity, and Acceleration Vectors

Get Focused

How many accelerators are there in a Smart car? (**Hint:** There are more than two.)

When a car is in motion, it changes position. The change in position is called a displacement. The car also travels with a given velocity, which may or may not be changing based on the acceleration. The terms *displacement*, *velocity*, and *acceleration* may not be as familiar to you as **distance** and **speed**. The collection of terms that make up the language of motion is perhaps larger than you think.

© Olaru Radian-Alexandru/shutterstock
A Smart car has more than two accelerators.

distance: the length of the path taken to move from one place to another

speed: distance travelled per unit of time

Lesson 1 challenged you to determine how distance, a familiar scalar quantity, was different than the vector quantity displacement. You did this by considering both quantities in a chuckwagon race and then using simulations to clarify the concepts. You expanded those ideas by considering their impact on both speed and velocity.

In this lesson and related lab activities you will not only review these ideas but clarify their use as you explore the following questions:

- How are speed and **velocity** calculated?
- What is the relationship between velocity and acceleration?

velocity: rate of change of position in relation to time

Module 1: Lesson 2 Assignments

Your teacher-marked Lesson 2 Assignment requires you to submit a response to the following:

- Lab—LAB 4, LAB 6, LAB 8, LAB 10, LAB 13, LAB 15, LAB 17, and LAB 18
- Try This—TR 2, TR 3, TR 4, and TR 5

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

Displacement Versus Distance

The personalized Smart car is painted pink and adorned with a rainbow.

When you travel in a Smart car, you experience a change in position. The change in position is defined by the vector quantity *displacement*. Displacement is a vector that points from the initial position to the final position, regardless of the path (distance) over which the object moved.

Watch and Listen

Go to your Physics 20 Multimedia DVD and watch the "Displacement" animation. Look for two differences between distance and displacement.

Self-Check

SC 1. What are two differences between distance and displacement that you observed?

Check your work with the answer in the appendix.

Lesson 2 Lab: Displacement

To reinforce your answers to the Self-Check and to expand your ability to calculate displacement, complete the following lab.

Introduction

The simulation used for this lab shows initial and final positions, displacement, and distance travelled as a ball is moved from one point to another.

This simulation lets you study the concepts of displacement and distance travelled. You can learn more about the simulation and how to use it by reading the Show Me found at the top of the simulation screen. As in Lesson 1, some of the symbols used in the simulation do not meet Alberta standards, so be prepared to

translate them into the indicated correct ones as you record your answers. For example, this simulation uses s for distance but you should use Δd for distance and $\Delta\vec{d}$ for displacement, as you read on pages 6 to 8 of your textbook.

Problem 1

How is the more familiar scalar quantity *distance* different than the vector quantity *displacement*?

Go to **www.learnalberta.ca**, and do a search using the keyword "displacement." From the list, choose the item that says "Displacement (Grade 11). Open the simulation; then continue with the procedure.

Procedure

Set up the simulation as follows:

- Reset ( ) the simulation.
- Turn on the gridlines ( ).
- Position ( ) the ball at $(x, y)_i = (10.0, -15.0)$ m. (Click the "Initial Position" button, and then click and hold the mouse button down as you drag the ball to the correct position. If you have difficulties, consult step 2 of the Show Me button at the top.)
- Drag the ball along any curved path to somewhere near $(x, y)_f = (-18.0, -8.9)$ m.

It may be hard to stop at exactly the same final position. You may want to try dragging the ball along a curved path similar to the blue path shown in Figure 1.

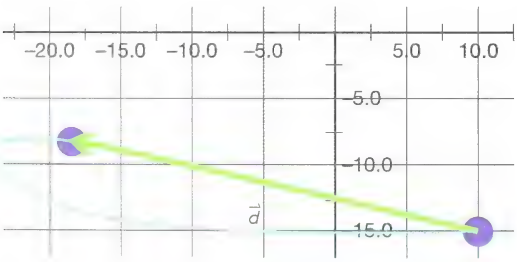


Figure 1

If you moved the ball from $(x, y)_i = (10.0, -15.0)$ m to somewhere near $(x, y)_f = (-18.0, -8.9)$ m, the simulation will display a green displacement vector $\Delta\vec{d}$. The simulation uses $\vec{d}$, but the accepted name in Physics 20 is $\Delta\vec{d}$. This vector is a measure of how the ball's position has changed. The magnitude (length) of the vector is indicated using the absolute value sign $|\Delta\vec{d}|$.

Observations and Analysis

LAB 1. Record the displacement and distance travelled, as indicated on the simulation. (Click on the "Data" button at the bottom.)

displacement $(|\Delta\vec{d}|, \theta)$ = ____________________

distance travelled (Δd) = ____________________

Remember, this simulation uses s for distance, but you should use Δd for distance and use $|\Delta \vec{d}|$ for the magnitude of the displacement. Remember, Δ means *change*.

LAB 2. Repeat the procedure by pressing the "Repeat" button ( ). Drag the ball along a different path to the same final coordinates. Again, record the displacement and distance travelled.

displacement ($|\Delta \vec{d}|$, θ) = ______________

distance travelled (Δd) = ______________

Self-Check

SC 2. Which value, distance or displacement, changed significantly? Which value remained constant in both cases? Explain your answer.

Check your work with the answer in the appendix.

Conclusions

Quantitatively, when an object undergoes a motion, the object's displacement is the vector that points from the initial position to the final position, regardless of the path on which the object moved.

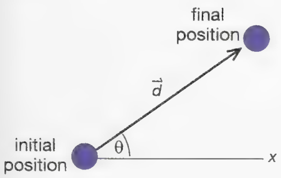


Figure 2

Displacement is a vector quantity whose magnitude (length) is equal to the straight-line distance from the initial position to the final position. The length of the arrow shown in Figure 2 represents the magnitude of the displacement vector. The direction of the displacement vector coincides with the direction from the initial to the final position. The direction of the displacement vector shown in Figure 2 is measured by the angle, θ, between the arrow and the direction of the positive x-axis.

The symbol for displacement to be used in Physics 20 is $\Delta \vec{d}$ (the simulation uses $\vec{d}$ so be careful). When writing the symbol by hand, include the Greek letter delta and the vector notation (a triangle in front and an arrow over the letter d).

Calculating Displacement

Displacement is calculated using the initial and final positions of the object.

Example Problem

An object that is initially at position $(x, y)_i = (10.0, -15.0)$ m moves to a final position of $(x, y)_f = (-18.0, -8.9)$ m. Calculate the object's displacement.

Solution

Start by drawing a diagram with all relevant quantities, as illustrated in Figure 3.

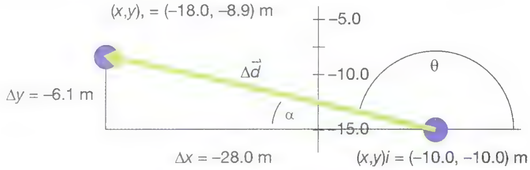


Figure 3

The displacement vector has an x component (displacement along the x-axis) equal to the change in the x position.

$$\begin{aligned} \Delta x &= x_f - x_i \\ \Delta x &= (-18.0\text{ m}) - (10.0\text{ m}) \quad (1) \\ \Delta x &= -28.0\text{ m} \end{aligned}$$

The displacement vector also has a y component (displacement along the y-axis) equal to the change in the y position.

$$\begin{aligned} \Delta y &= y_f - y_i \\ \Delta y &= (-8.9\text{ m}) - (-15.0\text{ m}) \quad (2) \\ \Delta y &= 6.1\text{ m} \end{aligned}$$

The triangle formed by these two components and the resultant vector is a right triangle; therefore, the Pythagorean theorem ($c^2 = a^2 + b^2$) can be applied to find the magnitude of the displacement.

$$\begin{aligned} (\Delta d)^2 &= (\Delta x)^2 + (\Delta y)^2 \\ \Delta d &= \sqrt{(\Delta x)^2 + (\Delta y)^2} \\ \Delta d &= \sqrt{(-28.0\text{ m})^2 + (6.1\text{ m})^2} \quad (3) \\ \Delta d &\doteq 28.656\,761\,85\text{ m} \end{aligned}$$

To calculate the direction of the displacement relative to the positive x-axis, first calculate its complement, α (see Figure 3).

$$\begin{aligned} \sin\alpha &= \frac{\text{opposite}}{\text{hypotenuse}} \\ \sin\alpha &= \frac{|\Delta y|}{\Delta d} \quad (4) \\ \alpha &= \sin^{-1}\left(\frac{6.1\text{ m}}{28.656\,761\,85\text{ m}}\right) \\ \alpha &\doteq 12.290\,257\,4^\circ \end{aligned}$$

Finally, using Figure 3, determine how to calculate θ.

$$\begin{aligned} \theta &= 180^\circ - \alpha \\ \theta &\doteq 180^\circ - 12.290\,257\,4^\circ \quad (5) \\ \theta &\doteq 167.707\,974\,26^\circ \end{aligned}$$

Note: When calculating a displacement, it is not sufficient to calculate only the magnitude, as in result (3). Displacement is a vector, and its magnitude is not the entire story. A vector's direction is just as important. Thus, only results (3) and (5) together provide a complete description for the total displacement.

$$\vec{d} = \Delta r$$

$$\vec{d} = (d, \theta) \qquad (6)$$

$\Delta\vec{d} = (28.7 \text{ m}, 168°)$, correct to 3 significant digits

LAB 3. Calculate the displacement (magnitude and direction) of the ball based on the following instructions:

- Reset ( ) the simulation, and turn on the gridlines ( ).
- Position ( ) the ball at $(x, y)_i = (10.0, -10.0)$ m.
- Drag the ball along any curved path to somewhere near $(x, y)_f = (-18.0, -10.0)$ m.

Show your work, and use the simulation to verify that the answer you calculated is correct.

Module 1: Lesson 2 Assignment

Remember to submit the answer to LAB 4 to your teacher as part of your Lesson 2 Assignment in the Module 1 Assignment Booklet.

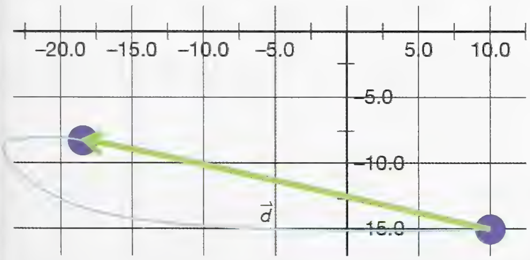
LAB 4. Calculate the displacement (magnitude and direction) of the ball when it is moved from the initial to the final position.

- initial position $(x, y)_i = (-10.0, 10.0)$ m
- final position $(x, y)_f = (15.0, -10.0)$ m

Show your work, and use the simulation to verify that the answer you calculated is correct.

Problem 2

Can the distance travelled ever be less than the magnitude of the displacement?



The distance travelled by the ball is defined as the length of the actual path travelled by the ball. If you place a string on the blue path and measure its length, you will determine the distance travelled by the ball. Distance travelled is denoted by the symbol *Δd*.

Procedure

- Reset ( ) the simulation.
- Turn on the gridlines ( ).
- Drag the ball to various positions on the simulation, and compare the distance travelled (Δd) with the magnitude of the displacement ($\left|\Delta\vec{d}\right|$).

Observations

LAB 5. Record your observations by completing the following table.

Trial 1	Trial 2	Trial 3
distance (Δd): ________ m displacement ($\left\|\Delta\vec{d}\right\|$): ________ m	distance (Δd): ________ m displacement ($\left\|\Delta\vec{d}\right\|$): ________ m	distance (Δd): ________ m displacement ($\left\|\Delta\vec{d}\right\|$): ________ m

Analysis

Module 1: Lesson 2 Assignment

Remember to submit the answer to LAB 6 to your teacher as part of your Lesson 2 Assignment in the Module 1 Assignment Booklet.

LAB 6. In general, the distance travelled will be ____________ than the magnitude of the displacement. The two will be equal only when the path taken is a ______________ line and when the path is traversed in a single direction (no backtracking).

Distance travelled, like the distance between two points, is a scalar quantity—in contrast to displacement, which is a vector quantity.

Self-Check

SC 3. Explain the difference between the scalar quantity *distance* and the vector quantity *displacement*, and give the proper symbol for each.

Check your work with the answer in the appendix.

Lab Summary

How is the more familiar scalar quantity *distance* different than the vector quantity *displacement*?

Distance travelled is a measure of how far an object has moved. Displacement is a measure of the magnitude of a change in position, and it includes an expression of direction.

Read

Review pages 6 to 10 of your textbook, and look particularly at the symbols for distance, position, and displacement. Also, notice how plus and minus signs are used to indicate direction in one dimension.

Self-Check

SC 4. On page 10 of your textbook, complete question 3 of "1.1 Check and Reflect."

SC 5. On page 10 of your textbook, complete question 4 of "1.1 Check and Reflect."

SC 6. On page 10 of your textbook, complete question 6 of "1.1 Check and Reflect."

Check your work with the answer in the appendix.

Try This

TR 1. Complete "2-2 QuickLab: Vector Walk" on page 79 of your textbook. This activity should be completed with a partner. If it is impossible to do the activity outdoors, the following adaptations are acceptable:

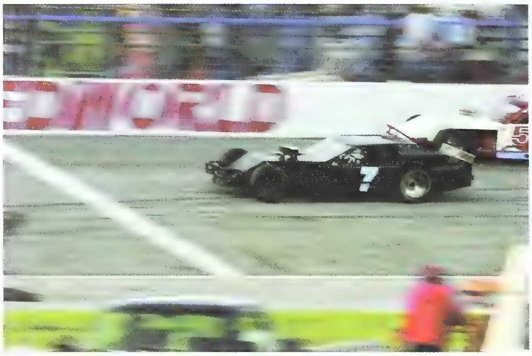
- Choose an indoor floor, and reduce the distances by a factor of 10 (e.g., a = 0.50 m).
- Choose 1-cm ruled graph paper, and reduce the distances by a factor of 100 (e.g., a = 5.0 cm).

Answer questions 1, 2, and 3 on page 79 of your textbook.

Average Velocity Versus Average Speed

When you are travelling in a vehicle, you experience a change in position. The rate at which you change position defines the vector quantity *velocity*.

Do not confuse velocity with speed. For example, if two cars are racing around a circular track, they can have a very large speed and a very low velocity all at the same time. In addition, they can be constantly changing velocity without changing speed. How can this be?



© Dennis Sabo/Dreamstime

Watch and Listen

Go to your Physics 20 Multimedia DVD and watch the animation titled "Velocity." Look for the differences between speed and velocity.

Self-Check

SC 7. What differences between speed and velocity did you notice?

Check your work with the answer in the appendix.

Lesson 2 Lab: Velocity

Introduction

The simulation used for this lab finds the average velocity and average speed for a ball as the ball is moved from one point to another.

This simulation lets you study the concepts of velocity and speed. You can learn more about the simulation and how to use it by reading the Show Me found at the top of the simulation screen. You will still have to use the correct notation that you have been taught.

Problem

How is the more familiar scalar quantity *speed* different from the vector quantity *velocity*?

Go to **www.learnalberta.ca**. You may be required to input a username and password. Contact your teacher for this information. Enter the search terms "average velocity" into the search bar. Choose the item called "Average Velocity (Grade 11)" from the list. Open the simulation; then continue with the procedure.

Procedure

LAB 7. Familiarize yourself with the simulation by completing the following steps:

- Open the Average Velocity simulation.
- Reset ( ) the simulation.
- Turn on the gridlines ( ).
- Position ( ) the ball at $(x, y)_i = (10.0, -15.0)$ m.
- Drag the ball along any curved path to somewhere near $(x, y)_f = (-20.0, -10.0)$ m.

Observations

Remember from the previous simulation that these authors use s for distance, but we use Δd. The authors also use $\vec{d}$ for displacement, but we use $\Delta\vec{d}$. The magnitude of the displacement should be indicated as $\left|\Delta\vec{d}\right|$.

In Figure 1, the following values are included in the display:

- distance travelled: $\Delta d = 36.6$ m
- displacement in the Cartesian system

  $\Delta\vec{d} = (\left|\Delta\vec{d}\right|, \theta)$

  $\Delta\vec{d} = (30.4 \text{ m}, 170.5°)$
- elapsed time: $\Delta t = 8.5$ s

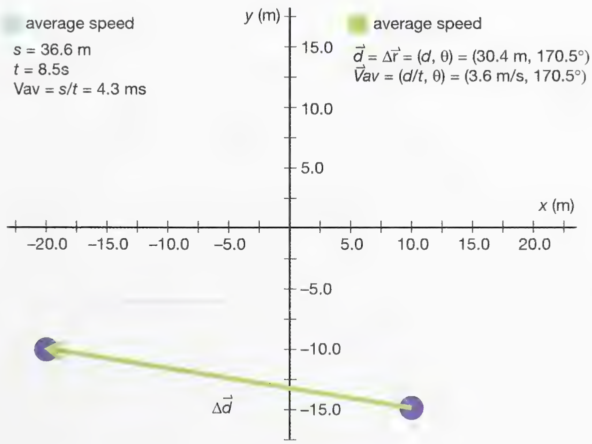


Figure 1

Note that the time figure given is based on how quickly the ball was moved from position 1 to position 2. Your time value should be different from that shown in Figure 1.

Figure 1 also indicates the average speed and average velocity expressed in the Cartesian system.

Average Velocity Versus Average Speed

Average velocity is defined as the ratio of displacement divided by time elapsed. It has both magnitude and direction.

Average speed is defined as the ratio of distance travelled divided by time elapsed. It does not have an expression of direction.

Quantity	Equation	SI Unit
average velocity (displacement divided by time)	$\vec{v}_{\text{ave}} = \frac{\Delta \vec{d}}{\Delta t}$	m/s, direction
average speed (distance divided by time)	$v_{\text{ave}} = \frac{\Delta d}{\Delta t}$	m/s

The following two example problems illustrate how to calculate average speed and average velocity and will illustrate the difference between the two quantities.

Example Problem 1

Given the distance and time data, what is the average speed?

$$v_{\text{ave}} = \frac{\Delta d}{\Delta t}$$
$$v_{\text{ave}} = \frac{36.6\text{ m}}{8.5\text{ s}}$$
$$v_{\text{ave}} = 4.30588\text{ m/s}$$
$$v_{\text{ave}} = 4.3\text{ m/s, correct to 2 significant digits}$$

The applet doesn't round its values. It just chops off any extra digits.

Example Problem 2

Given the displacement and time data, what is the average velocity?

Note that to divide a vector ($\Delta\vec{d}$) by a scalar (Δt), you divide its magnitude $\left|\Delta\vec{d}\right|$ by the scalar and do not change the angle.

$$\vec{v}_{\text{ave}} = \frac{\left|\Delta\vec{d}\right|}{\Delta t}$$

$$\vec{v}_{\text{ave}} = \frac{30.4\ \text{m}}{8.5\ \text{s}}$$

$$\vec{v}_{\text{ave}} = \left(3.576\ \text{m/s},\ 170.5^{\circ}\right)$$

$$\vec{v}_{\text{ave}} = \left(3.6\ \text{m/s},\ 171^{\circ}\right),\ \text{correct to 2 significant digits}$$

Note the difference in magnitude between the average velocity and average speed.

- magnitude of average velocity $\left|\Delta\vec{v}_{\text{ave}}\right| = 3.6$ m/s
- average speed $v_{\text{ave}} = 4.3$ m/s

The two values are not equal! This is why the magnitude of the average velocity cannot be denoted by the symbol v_{ave}.

Analysis

Module 1: Lesson 2 Assignment

Remember to submit the answer to LAB 8 to your teacher as part of your Lesson 2 Assignment in the Module 1 Assignment Booklet.

LAB 8. Calculate the average speed and the average velocity for a ball that is moved according to the following instructions.

- Reset ( ) the simulation, and position ( ) the ball at $(x, y)_{\text{i}} = (10.0, -5.0)$ m.
- Drag the ball along any curved path to somewhere near $(x, y)_{\text{f}} = (-20.0, -10.0)$ m.

a. Show the average speed calculations.

b. Show the average velocity calculations.

LAB 9. Using a procedure similar to LAB 2, calculate the average speed and the average velocity for a ball that is moved from $(x, y)_i = (0.0, -12.0)$ m to $(x, y)_f = (5.0, -16.0)$ m.

a. Show the average speed calculations.

b. Show the average velocity calculations.

c. Do your answers approximately correspond to the values given in the simulation?

Module 1: Lesson 2 Assignment

Remember to submit the answer to LAB 10 to your teacher as part of your Lesson 2 Assignment in the Module 1 Assignment Booklet.

LAB 10. Why is the average speed always greater than the magnitude of the average velocity?

LAB 11. Could there ever be a situation in which it is the other way around? Explain.

Lab Summary

How is the more familiar scalar quantity speed different from the vector quantity velocity?

The familiar quantity of speed has only a magnitude determined by the change in distance divided by the change in time. The vector quantity velocity has a direction and a magnitude which is determined by the change in position (displacement) divided by the change in time.

Self-Check

SC 8. On page 75 of your textbook, complete question 3 of "2.1 Check and Reflect."

SC 9. On page 75 of your textbook, complete question 7 of "2.1 Check and Reflect."

SC 10. On page 75 of your textbook, complete question 9 of "2.1 Check and Reflect."

Check your work with the answer in the appendix.

Acceleration

When you travel in a car, you experience a change in position over a given period of time. And the rate of change in position is defined by the vector quantity velocity. But what happens if the velocity changes too? The rate of change of velocity is defined by the vector quantity **acceleration**.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Consider this example of acceleration: When the light turns green at an intersection, applying pressure to the gas pedal causes the drive train (engine and transmission) to produce an acceleration that changes the velocity of the car. The concept of acceleration, however, is not always that simple. The direction of the acceleration vector is the direction of the change in velocity, which may not be in the same direction as the velocity itself.

acceleration: a measure of the rate of change of velocity

Acceleration is expressed as an equation, $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$.

Quantity	Symbol	SI Unit
acceleration	$\vec{a}$	m/s2
change in velocity	$\Delta \vec{v}$	m/s
time interval	Δt	s

Δ means *change*.

Watch and Listen

Go to your Physics 20 Multimedia DVD, and watch the animation titled "Acceleration" to see the effect of acceleration on motion.

Self-Check

SC 11. Explain what happens when the direction of the acceleration is opposite to the direction of the velocity.

SC 12. What happens when the direction of the acceleration is perpendicular to the direction of the velocity?

Check your work with the answer in the appendix.

Lesson 2 Lab: Acceleration

Introduction

The simulation used for this lab contrasts the concepts of velocity and acceleration. As you complete it, you will able to answer the question posed at the beginning of this lesson about how many accelerators there are in a Smart car.

This simulation lets you study and compare the concepts of velocity and acceleration. You can learn more about the simulation by reading the Show Me found at the top of the simulation screen.

Problem

What is the relationship between velocity and acceleration? Can you accelerate without changing speed?

Go to **www.learnalberta.ca**. You may be required to input a username and password. Contact your teacher for this information. Enter the search terms "2D acceleration" in the search bar. Choose the item called "2D Acceleration (Grade 11)" from the list. Open the simulation; then continue with the procedure.

Procedure

To complete the Observations and Analysis section of the lab, you will need to adjust either the initial velocity or acceleration vectors on the simulation.

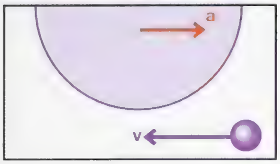
This can be done by clicking on the desired vector and dragging it out.

v Click and drag the velocity vector to change the initial velocity of the object.

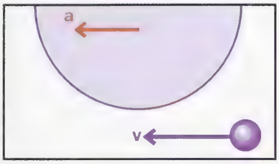
a Click and drag the acceleration vector at any time to adjust the acceleration of the object.

Observations and Analysis

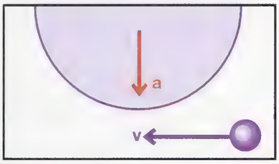
LAB 12. Set up the simulation for each of the listed conditions in the following table. Then determine whether the initial motion of the moving object is speeding up, slowing down, or changing directions. Choose *speed up*, *slow down*, or *change direction* to describe the initial motion of the moving object.

a. 

Acceleration is in the opposite direction of the initial velocity.

b. 

Acceleration is in the same direction as the initial velocity.

c. 

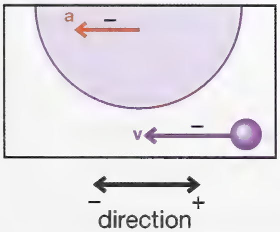
Acceleration is at right angles to the initial velocity.

Module 1: Lesson 2 Assignment

Remember to submit the answer to LAB 13 to your teacher as part of your Lesson 2 Assignment in the Module 1 Assignment Booklet.

LAB 13. According to the figure below, the velocity and the acceleration have a negative direction. Compare this to your observations from Lab 12.

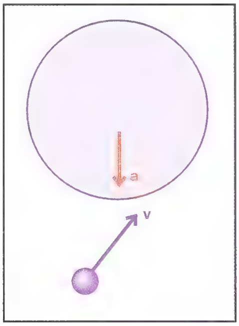
a. Does a negative acceleration necessarily mean that something is slowing?



b. What orientation of velocity and acceleration will cause something to initially slow down?

c. What orientation of velocity and acceleration will cause something to initially speed up?

LAB 14. On the simulation, set the initial acceleration and velocity as shown in the following figure. Run the simulation, and observe the motion of the object. Explain what happened to the direction of the initial velocity, and suggest a common type of motion that follows a parabolic path similar to the one you observed.



Module 1: Lesson 2 Assignment

Remember to submit the answer to LAB 15 to your teacher as part of your Lesson 2 Assignment in the Module 1 Assignment Booklet.

LAB 15. Set up the simulation to illustrate the motion of a baseball that is thrown straight up.

a. Above each of the following words, draw the initial velocity vector and the constant acceleration vector.

velocity acceleration

b. Is there a point on the trajectory where the ball has zero velocity? Where on the trajectory does this occur?

c. Is there a point on the trajectory where the ball has zero acceleration? Explain.

LAB 16. On the simulation, add five obstacles by clicking the Obstacles box (☑ Obstacles). By adjusting only the acceleration, try to move the object over each obstacle, starting with obstacle 0 and ending with obstacle 4. Does the acceleration "steer" the object? Explain.

Module 1: Lesson 2 Assignment

Remember to submit the answers to LAB 17 and LAB 18 to your teacher as part of your Lesson 2 Assignment in the Module 1 Assignment Booklet.

LAB 17. Based on your observations from the simulation, do you think it is possible for an object to accelerate yet neither speed up nor slow down? Explain why or why not.

LAB 18. Based on your observations from all the previous exercises, it is clear that acceleration will change the magnitude and/or direction of the velocity. With this in mind, complete the following list of accelerators common to all vehicles.

a. the ________________________, which causes an acceleration that maintains or changes the car's velocity, controlled by the gas pedal

b. the _________, which causes an acceleration that opposes the car 's velocity, controlled by the brake pedal

c. the ____________________, which causes an acceleration that changes only the direction of the car's velocity

Lab Summary

What is the relationship between velocity and acceleration? Can you accelerate without changing speed?

Acceleration is a measure of the change in velocity during a given time interval. Therefore, acceleration is a measure of the rate of change of velocity. Since a change in direction changes the velocity but not necessarily the speed, you can accelerate without changing speed.

Self-Check

SC 13. On page 30 of your textbook, complete question 1 of "1.3 Check and Reflect."

Check your work with the answer in the appendix.

Module 1: Lesson 2 Assignment

Remember to submit the answers to the questions in TR 2, TR 3, TR 4, and TR 5 to your teacher as part of your Lesson 2 Assignment in the Module 1 Assignment Booklet.

Reflect and Connect

Recall the questions about displacement, velocity, and acceleration in Get Focused at the beginning of this lesson. If two Smart cars depart from the same location at the same time and travel different routes to the same final destination and arrive at the same time, prepare to explain why the following statements are true. Then submit your answers to your teacher for marking.

Try This

TR 2. The cars have travelled different distances but have the same displacement.

TR 3. The average velocity of each car is identical even though they travelled at different speeds.

TR 4. When the brakes on the cars were used, the acceleration was not necessarily negative.

TR 5. The steering wheel on each car was used to change the velocity of the car without changing the speed.

Discuss

The Smart car was designed with extensive safety features to accommodate large accelerations that can occur during a collision. Safety features include the following:

- a very rigid tridion safety cell to shield and protect the driver and passenger
- emergency tensioning devices (ETD) to tighten seat belts
- airbags
- antilock brakes
- a deformable steering column

Use the Internet as a research tool to find out how each of these safety systems is designed to function in the event of a collision. Try search words such as “Smart car tridion,” “Smart car crash test,” and “Smart car emergency tensioning devices.”

One of the safety systems listed does not decrease the acceleration experienced by the driver in a collision. Which safety feature is it? Why is it designed to work this way? Place your findings in the discussion area.

Reflect on the Big Picture

In this lesson you expanded your knowledge about acceleration, velocity, and displacement. You are better able to describe an object in motion and understand how its motion is changing. You have seen another non-intuitive idea about velocity—it can be changing rapidly even if you are travelling at a constant speed. Have you thought about how these ideas are extensions of the ideas from Lesson 1?

To help you reflect on your learning experience in this lesson, complete at least one of these activities:

- Create a mind map that includes the concepts developed in this lesson and those from Lesson 1.

- Create a set of study questions that would help a new learner master the concepts from this lesson.

Store your completed reflection in your Physics 20 course folder.

Going Beyond

TR 6. Complete “1-2 Decision-Making Analysis: Traffic Safety Is Everyone’s Business” on pages 12 and 13 of your textbook. If you don’t have access to **www.pearsoned.ca/school/physicssource**, begin with a web search using key words such as “tachograph” and “road safety.”

Module 1: Lesson 2 Assignment

Ensure that you have completed all of the questions in the Lesson 2 Assignment. Contact your teacher to find out if you should submit your assignment now or wait until you have completed the Module 1 Assignment Booklet.
Add to the KWL chart you started in Lesson 1. Continue to store your chart in your Physics 20 course folder.

Lesson Summary

In this lesson and related lab activities you explored the following questions:

- How are speed and velocity calculated?
- What is the relationship between velocity and acceleration?

Displacement Versus Distance

Distance travelled is a measure of how far an object has moved. Displacement is a measure of the magnitude of a change in position, and it includes an expression of direction.

Quantity	Symbol	SI Unit
displacement (a vector quantity written as $\Delta\vec{d}$ with an arrow on top)	$\Delta\vec{d}$	m, direction
magnitude of the displacement	$\lvert\Delta\vec{d}\rvert$	m
distance (a scalar and therefore written as Δd without an arrow)	Δd	m

Note that the magnitude of a displacement, $\lvert\Delta\vec{d}\rvert$, is, in general, different from the distance travelled (Δd).

Average Velocity Versus Average Speed

Average velocity is defined as the ratio of displacement divided by time elapsed. It has both magnitude and direction. Average speed is defined as the ratio of distance travelled divided by time elapsed. It does not have an expression of direction.

Quantity	Equation	SI Unit
average velocity (displacement divided by time)	$\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t}$	m/s, direction
average speed (distance divided by time)	$v_{ave} = \frac{\Delta d}{\Delta t}$	m/s

Acceleration is a measure of the change in velocity during a given time interval. Therefore, acceleration is a measure of the rate of change of velocity.

Expressed as an equation, it is $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$ or $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$.

Quantity	Symbol	SI Unit
acceleration	$\vec{a}$	m/s^2
change in velocity	$\Delta \vec{v}$	m/s
time interval	Δt	s

Δ means *change*.

Lesson Glossary

acceleration: a measure of the rate of change of velocity in relation to time

distance: the length of the path taken to move from one place to another

speed: a measure of the distance travelled per unit of time

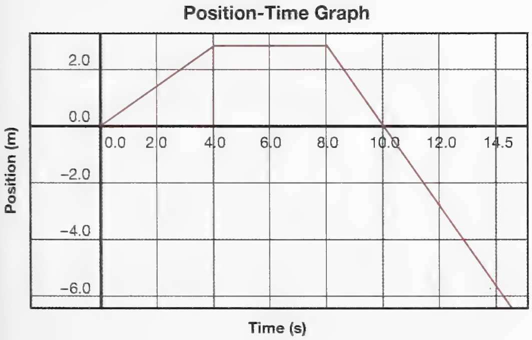
velocity: a measure of the rate of change of position in relation to time

Lesson 3—Graphical Analysis of Uniform Motion

Get Focused

Have you ever used a graph to tell a story? Probably not, but graphs are excellent storytellers when it comes to motion. Here is an example.

When the bell rang, Taylor left class. She walked down the hall to her locker, moving at 1.0 m/s. She paused at her locker to grab her coat. Then she ran back towards her classroom, passing it at 2.0 m/s as she made her way to the school exit.



Essentially, this graph tells the same short story. It is a story of motion—of how an object or person changes position as time passes. Graphs are a powerful way to express and analyze the motion of such things as vehicles, trains, satellites, and other moving objects.

A graph can also be used to compare motion, such as that of an athlete. For example, two cyclists are travelling along the same racetrack. They depart at different times and they travel at different velocities. How could you accurately predict where and when they will meet?

In this lesson you will describe and compare **one-dimensional**, **uniform motion** using **position-time graphs** and **velocity-time graphs**. There are five parts to the lesson. Each part has an essential question for you to answer.

- Part 1: How can you interpret position-time graphs for motion in one dimension?
- Part 2: How do you determine velocity using a position-time graph?
- Part 3: How can you compare observed motions with position-time graphs?
- Part 4: How can you interpret velocity-time graphs for motion in one dimension?
- Part 5: How do you determine displacement using a velocity-time graph?

one-dimensional motion: motion in a straight line

position-time graph: a graph showing the position of an object at varying times, where time is the independent variable and position is the dependent variable

uniform motion: motion at constant speed in a straight line

velocity-time graph: a graph showing the velocity of an object at varying times, where time is the independent variable and velocity is the dependent variable

Module 1: Lesson 3 Assignments

Your teacher-marked Lesson 3 Assignment requires you to submit a response to the following:

- Try This—TR 1, TR 2, TR 3, TR 4, TR 6, TR 8, TR 10, TR 11, TR 12, TR 13, and TR 14

You must decide what to do with the questions that are not marked by your teacher.

Remember that these other questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

Watch and Listen

Go to your Physics 20 Multimedia DVD, and watch the "Position-Time" animation. Look for the answer to the following Self-Check question.

Self-Check

SC 1. How does the graph line differ from the path that Taylor took during that time?

Check your work with the answer in the appendix.

Part 1: Interpreting Position-Time Graphs for Motion in One Dimension

The fundamental graph used to visualize motion is the position-time graph. This type of graph is used to visualize the change in position for an object or person moving along a straight path during a given time interval. There is a large amount of information about the position of the moving object or person on this kind

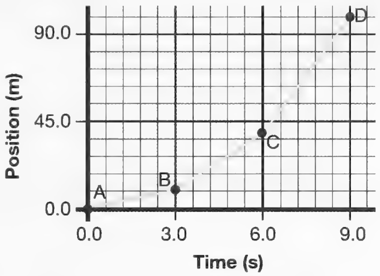
of graph. The following Try This activity involves reading and interpreting position-time graphs to determine specific information.

Module 1: Lesson 3 Assignment

Remember to submit the answers to TR 1, TR 2, and TR 3 to your teacher as part of your Lesson 3 Assignment in the Module 1 Assignment Booklet.

Try This

TR 1. Jordan is motorcycling along a straight path. The position-time graph illustrates his position (measured from the starting position) plotted against time. What can this graph tell you about Jordan's movement and location?



a. Describe Jordan's position at the following points:

A: ______ m, B: ______ m, C: ______ m, D: ______ m

b. What is his displacement in the first 3.0 s?

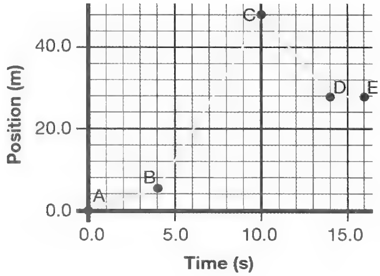
c. What is his displacement in the first 9.0 s?

d. What is his displacement when motorcycling from point B to point D?

e. Is all of the motion in the same direction? How do you determine this by using the graph?

TR 2. A basketball rolls across the gym floor, is hit by another ball, bounces off the far wall, and gets trapped under a chair on the gym floor.

© zimmytws/shutterstock



a. What was the ball's displacement when it hit the far wall of the gym, and how long did it take to get there? ___________ m, ____________ s

b. What is different about the ball's motion from 4 s to 10 s (from point B to point C) compared to the motion from 10 s to 14 s (from point C to point D)?

c. Use the terms *forward*, *backward*, and *stopped* to describe the motion of the ball between the following points:

A–B __________ B–C ____________

C–D __________ D–E____________

d. How far away is the chair from the far wall of the gym?

TR 3. A lawn mower is pushed along a straight path. The graph shows the position of the mower over a 16.0-s time interval.

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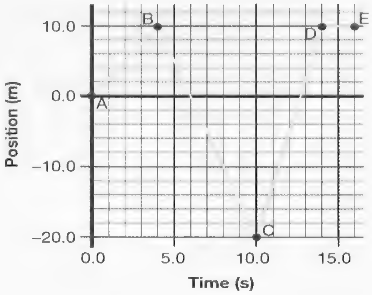


a. How many times was the mower at the starting position?

b. Where is position C relative to the starting position—in front or behind? Is this a positive (+) or negative (–) position?

c. Which two motions are in the same direction?

A. A–B and B–C
B. A–B and C–D
C. B–C and D–E
D. B–C and C–D

d. The motion switched direction two times. At which two points did the direction of the motion reverse? Explain how this is indicated on the graph.

e. Explain how the position-time graph for the lawn mower could be used to develop an automated program to control the motion of a self-propelled mower.

Part 2: Determining Velocity Using a Position-Time Graph

Read

In order to know how to get even more information from a graph, read "Position-time Graphs and Uniform Motion" on pages 11 and 12 of your textbook. You will see that the concepts learned in Lessons 1 and 2 are being used here very effectively. Look for ways that graphs can help find answers to problems.

Self-Check

SC 2. What information does the slope of the graph line in a position-time graph tell you?

Check your work with the answer in the appendix.

Read

Look for the answers to the following Self-Check questions as you read "Speed and Velocity" and "Frame of Reference" on pages 12 to 14 of your textbook.

Self-Check

SC 3. How can two objects have the same speed but have different velocities?

SC 4. If you change the frame of reference, how could that affect the velocity?

Check your work with the answer in the appendix.

Here is a different way of looking at the situation. Recall from Lesson 1 that velocity is defined as the rate of change of position of an object. Mathematically, it is defined as

$$\vec{v}_{\text{ave}} = \frac{\text{change in position}}{\text{change in time}}$$

$$\vec{v}_{\text{ave}} = \frac{\text{displacement}}{\text{change in time}}$$

$$\vec{v}_{\text{ave}} = \frac{\Delta\vec{d}}{\Delta t} \qquad (1)$$

When applied to one-dimensional motion on the x-axis and using x components, the definition becomes

$$V_{\text{x}} = \frac{\Delta d_{\text{x}}}{\Delta t}$$

$$= \frac{\Delta x}{\Delta t}$$

$$= \frac{x_{\text{final}} - x_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}} \qquad (2)$$

How does the definition of velocity, as given by equation (2), relate to a position-time graph? Look at segment DVD in the position-time graph in Figure 1. The slope of that segment can be found using the formula

$$\text{slope} = \frac{\text{rise}}{\text{run}}$$

$$= \frac{\text{vertical change}}{\text{horizontal change}}$$

$$= \frac{x_{\text{final}} - x_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}}$$

This is the right side of equation 2, so the velocity and the slope are the same.

This shows that the slope of the line on a position-time graph is equal to the velocity of the object.

The slope of a position-time graph for a given time interval in which the graph is a straight line is equal to the velocity in that time interval.

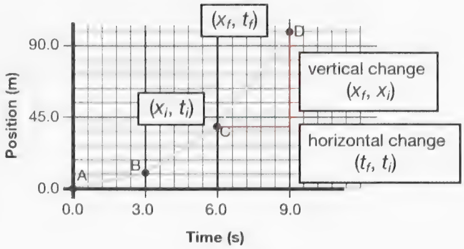


Figure 1

Self-Check

SC 5. Complete question 10 of "1.2 Check and Reflect" on page 20 of your textbook, using slope to determine velocity for each lettered stage of the motion.

Check your work with the answer in the appendix.

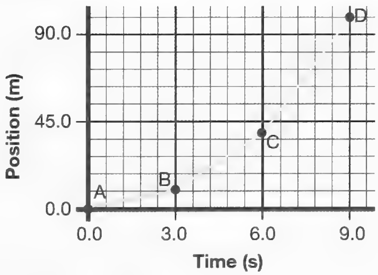
Module 1: Lesson 3 Assignment

Remember to submit the answer to TR 4 to your teacher as part of your Lesson 3 Assignment in the Module 1 Assignment Booklet.

Try This

TR 4. Calculate the velocity (slope) for each time interval in the following position-time graph. Show all of your work, including correct units and directions using a positive/negative *x*-axis.

a. velocity from point A to point B
b. velocity from point B to point C
c. velocity from point C to point D



Part 3: Comparing Observed Motions with Position-Time Graphs

It can be difficult to visualize the motion of an object based on nothing more than a position-time graph. It is also difficult to imagine the graph that represents a motion that you are watching.

You will use a simulation to visualize and compare the actual motion of an object with its representative position-time graph.

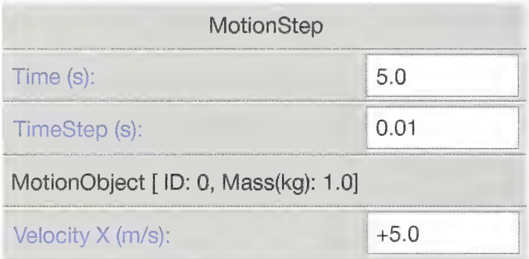
Go to **www.learnalberta.ca**. Enter the search terms "1D uniform motion builder" in the seearch bar. Choose the item called "1D Uniform Motion Builder Graphing (pos, vel) (Grade 11)" from the list. Open the simulation. If you cannot see the Play and Pause buttons on the bottom of the page, you may need to adjust the window. Click on the coloured title bar at the top, and drag the window to the upper right-hand corner of your screen. Then expand the window down by holding your cursor on the bottom border, clicking on the double-headed arrow that appears and dragging it down till you clearly see the bottom buttons. You can adjust the side margins in a similar way to remove the unused black areas. It will be convenient to have this window tight to the right side of your screen. After these adjustments, continue with Try This. You can learn more about the simulation and how to use it by reading the Show Me found at the top of the simulation screen.

Try This

TR 5. Using the simulation, generate a position-time graph for an object that moves at +5.0 m/s for 5.0 s and then at +10.0 m/s for another 5.0 s.

Step 1: On the simulation, click "Reset" ( ) and then "Add" ( ) to add an object.

Step 2: In the "MotionStep EditorDialog" window, enter a time of 5.0 s and a velocity of +5.0 m/s. Click OK.



MotionStep	
Time (s):	5.0
TimeStep (s):	0.01
MotionObject [ID: 0, Mass(kg): 1.0]	
Velocity X (m/s):	+5.0

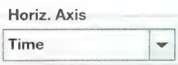
Step 3: Repeat steps 1 and 2, entering a time of 5.0 s and a velocity of +10.0 m/s. Click OK.

Step 4: Click "Play" ( ) and watch the moving object ( ) travel at two different velocities.

Step 5: To view the position-time graph, do the following:

- Click "Graph."

- Set "Horiz. Axis" to "Time" by clicking on the down arrow on the right of the horizontal axis box. Then move the slider on the right up to see "Time" and click on it.



- Set "Vert. Axis" to displacement (x0).

- Click "Fit Graph to the Screen." (Fit Graph to the Screen).

Step 6: To view the slope, expand the graph window by dragging the margin to the right with the double-headed arrow as described earlier until you see the “Slope Mode” button ( ). Click the “Slope Mode” button. Click and hold the mouse cursor over the graph line, and the slope value (m/s) will be indicated under Output. You can expand the graph down by dragging the bottom border of the window down and then dragging down the line under the “Zoom Out” button. You can also use the arrows under the “Zoom In” button, but the size adjustment is not as flexible.

Verify that your graph is identical to Figure 2. The slope value is displayed under Output and represents the object’s velocity at the selected time.

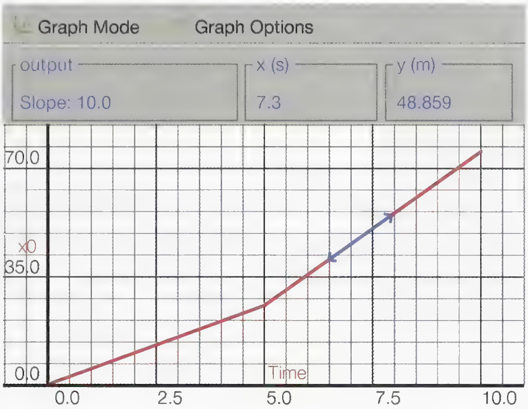


Figure 2

Module 1: Lesson 3 Assignment

Remember to submit the answer to TR 6 to your teacher as part of your Lesson 3 Assignment in the Module 1 Assignment Booklet.

TR 6. On the simulation, click “Reset” ( ). Clear all motion steps from the simulation by clicking each motion step and clicking “Remove” ( ).

Enter the following new motion steps on the simulation by clicking “Add” ( ):

- 5.0 s at +4.0 m/s
- 3.0 s at +14.0 m/s
- 2.0 s at +6.0 m/s

a. Play the motion, and generate the position-time graph. Draw the graph in the space to the right.
b. Using the “Slope Mode” button, determine and label the velocity for each time interval on your graph.

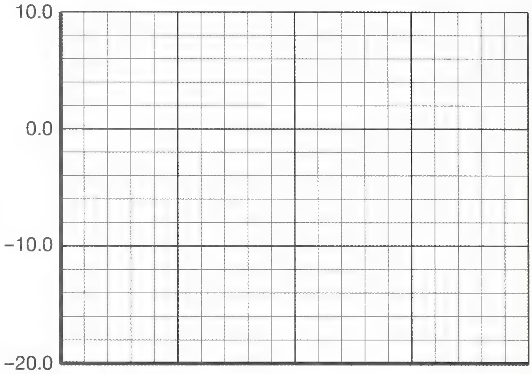
TR 7. On the simulation, click "Reset" ( ). Clear all motion steps from the simulation by clicking each motion step and clicking "Remove" ( ).

Enter the following new motion steps on the simulation by clicking "Add" ( ).

- 5.0 s at –4.0 m/s
- 3.0 s at +10.0 m/s
- 2.0 s at –2.5 m/s

a. Play the motion and generate the position-time graph. Draw the graph in the space to the right.

b. Using the "Slope Mode" button, determine and label the velocity for each time interval on your graph.



Part 4: Interpreting Velocity-Time Graphs for Motion in One Dimension

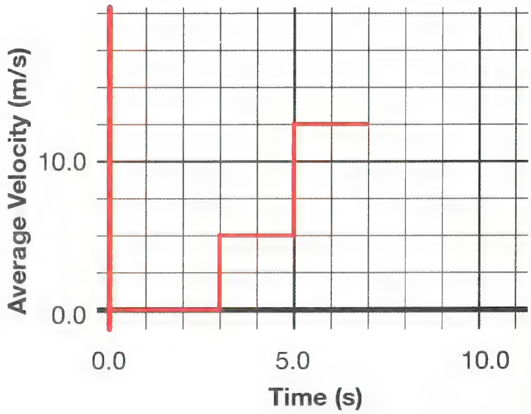
Velocity-time graphs also tell a story about motion. These graphs contain more information than you may expect. They can be used to visualize the velocity of an object moving along a straight path during a given time interval. The following Try This activity involves reading and interpreting velocity-time graphs to determine specific information.

Module 1: Lesson 3 Assignment

Remember to submit the answer to TR 8 to your teacher as part of your Lesson 3 Assignment in the Module 1 Assignment Booklet.

Try This

TR 8. A car travels along a straight road. The following simplified graph shows the car's average velocity over several selected time periods during a 7.0-s time interval.



a. What was the average speed of the car during the 0.0–3.0-s time interval?
_________ m/s

b. What was the average speed of the car during the 3.0–5.0-s time interval?
_______ m/s

c. What was the average speed of the car during the 5.0–7.0-s time interval?
_______ m/s

d. Using $v_{ave} = \frac{\Delta d}{\Delta t}$, calculate how far the car travels during the 0.0–3.0-s time interval.

e. How could you determine the distance that the car would travel for the entire 7-s interval?

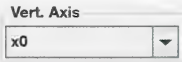
TR 9. A car travels along a straight path with three different velocities, as shown in the following table.

Time Interval (s)	Velocity (m/s)
0.0–3.0	2.0
3.0–6.0	10.0
6.0–8.0	6.0

- On the simulation, click "Reset" ( ). Clear all motion steps from the simulation. Enter each time interval and velocity in the simulation, and play the motion. Complete the graph by generating a velocity-time graph on the simulation.
- Click "Graph."

- Set the "Horiz. Axis" to "Time."

- Set the "Vert. Axis" to velocity ("x0").

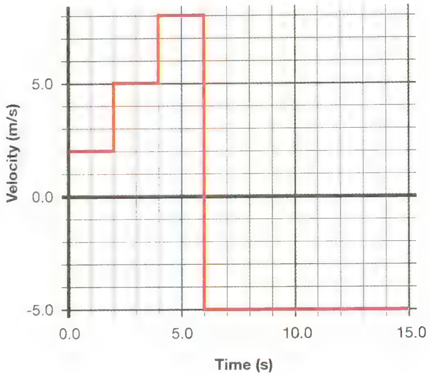


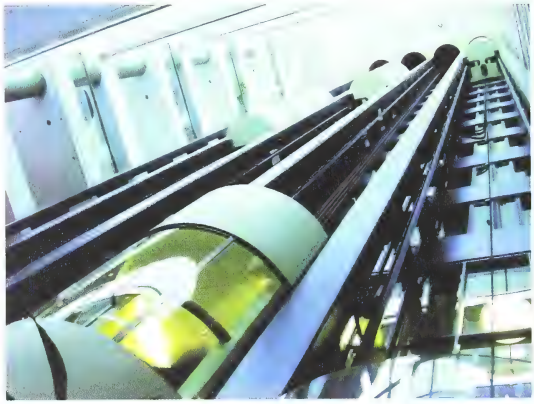
- Click "Fit Graph to the Screen." (
).

Module 1: Lesson 3 Assignment

Remember to submit the answer to TR 10 to your teacher as part of your Lesson 3 Assignment in the Module 1 Assignment Booklet.

TR 10. An elevator moves up and down between floors in a building. The following graph shows the velocity of an elevator that was moving over a 15.0-s time interval.





a. What is the fastest velocity? During what time interval does this occur?

b. What is the lowest velocity? During which time interval does this occur?

c. Does the elevator move in two different directions? How can this be determined using the graph, and how is this illustrated using the *x*-axis?

d. The graph illustrates four distinct "phases" for the motion. Complete the following table, and then enter these values into the simulation to reproduce the horizontal equivalent of the elevator's motion.

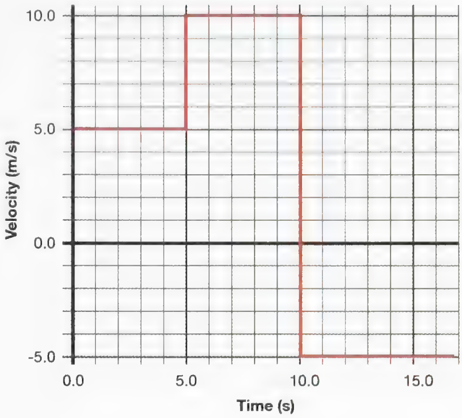
Time Interval (s)	Velocity (m/s)
________	________
________	________
________	________
________	________

Part 5: Determining Displacement Using a Velocity-Time Graph

Velocity-time graphs reveal more than just the velocity of a moving object. They can also be used to determine the object's displacement during a specific time period.

For example, the velocity-time graph on the right illustrates three phases of motion for an object travelling along a straight path over a given time interval. There are three different velocities.

- 5.0 s at +5.0 m/s
- 5.0 s at +10.0 m/s
- 7.0 s at –5.0 m/s



The displacement in each phase can be calculated using

$\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t}$ for each phase of the motion as follows:

$$\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t}$$

$$\Delta \vec{d} = \vec{v}_{ave} \Delta t$$

$$\begin{aligned}\Delta \vec{d}_1 &= \vec{v}_{ave_1} \Delta t_1 \\ &= (+5.0 \text{ m/s})(5.0 \text{ s}) \\ &= +25 \text{ m}\end{aligned}$$

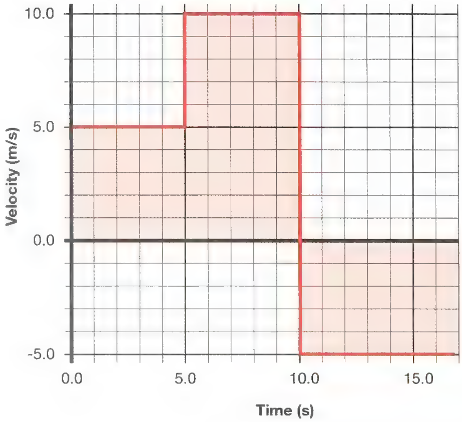
$$\begin{aligned}\Delta \vec{d}_2 &= \vec{v}_{ave_2} \Delta t_2 \\ &= (+10.0 \text{ m/s})(5.0 \text{ s}) \\ &= +50 \text{ m}\end{aligned}$$

$$\begin{aligned}\Delta \vec{d}_3 &= \vec{v}_{ave_3} \Delta t_3 \\ &= (-5.0 \text{ m/s})(7.0 \text{ s}) \\ &= -35 \text{ m}\end{aligned}$$

The total displacement is the sum of all three phases of motion.

$$\begin{aligned}\Delta \vec{d}_{total} &= \Delta \vec{d}_1 + \Delta \vec{d}_2 + \Delta \vec{d}_3 \\ &= (+25 \text{ m}) + (+50 \text{ m}) + (-35 \text{ m}) \\ &= +40 \text{ m}\end{aligned}$$

There is another method of determining the total displacement using the velocity-time graph. On the graph to the right, the area between the line and the time axis is also equal to the product of the velocity and time. The shaded area represents the total displacement, where the area above the time axis is positive and the area below is negative.



$$\Delta\vec{d}_{\text{total}} = \text{area above} + \text{area below}$$

$$\begin{aligned}\Delta\vec{d}_{\text{total}} &= (+75) + (-35) \\ &= +40\end{aligned}$$

The area between a velocity-time graph and the time axis for a given interval of time is equal to the displacement of the object in that interval of time.

Self-Check

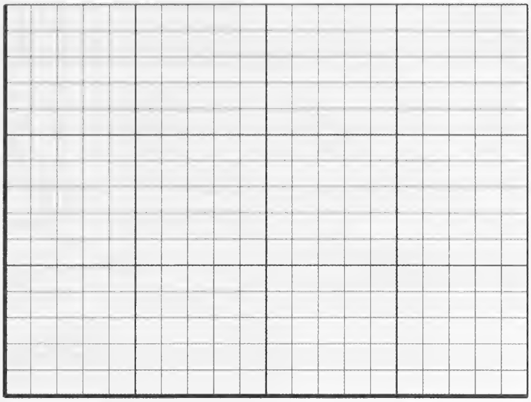
SC 6. A ball rolls along a straight path with the following velocity and time intervals:

- 5.0 s at +5.0 m/s
- 8.0 s at –10.0 m/s
- 4.0 s at –3.0 m/s
- 3.0 s at +8.0 m/s

Use the simulation to produce a velocity-time graph for the data above. Click the area "Integrate" button ( ) and sweep out the area from left to right to determine the total displacement. Sweeping left to right gives a green area, and the simulation displays the area (integral) under Output.

© elenathewise/BigStockPhoto

Complete the graph by drawing the velocity-time graph.



Total displacement (integral) as indicated in the simulation Output: _______ m

Check your work with the answer in the appendix.

Module 1: Lesson 3 Assignment

Remember to submit the answer to TR 11 to your teacher as part of your Lesson 3 Assignment in the Module 1 Assignment Booklet.

Try This

TR 11. A ball rolls along a straight path with the following velocity and time intervals:

- 3.0 s at +15.0 m/s
- 7.0 s at +20.0 m/s
- 6.0 s at –30.0 m/s
- 4.0 s at +3.5 m/s

Use the simulation to produce a velocity-time graph. Click the area "Integrate" button ( ), and sweep out the area from left to right to determine the following:

a. total displacement: _______ m
b. displacement in the first 10 s: _______ m
c. displacement in the last 10 s: _______ m
d. displacement in the 5.0–15.0-s time interval: _______ m

Self-Check

SC 7. Go to page 20 of your textbook and complete question 3 of "1.2 Check and Reflect."

SC 8. Go to page 20 of your textbook and complete question 5 of "1.2 Check and Reflect."

SC 9. Go to page 20 of your textbook and complete question 8 of "1.2 Check and Reflect."

Check your work with the answer in the appendix.

Read

Go to pages 14 to 17 of your textbook and read "Comparing the Motion of Two or More Objects on a Position-time Graph" to see examples of how problems involving two moving objects are solved.

SC 10. Go to page 20 of your textbook and complete question 12 of "1.2 Check and Reflect." Use a graph in your solution.

Check your work with the answer in the appendix.

Watch and Listen

Go to your Physics 20 Multimedia DVD, and watch the "Comparing Motion Using a Position-Time Graph" animation. Read the printed scenario at the bottom before you click on "Start Launch." Look for the answer to SC 11 as you view the animation.

Self-Check

SC 11. In the animation you just watched, how can you tell who won by looking at the graph lines?

Check your work with the answer in the appendix.

Module 1: Lesson 3 Assignment

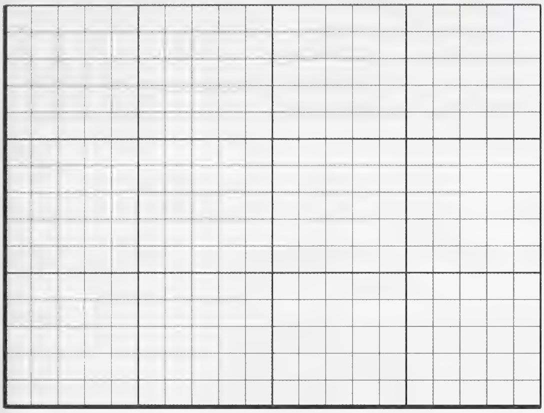
Remember to submit the answers to TR 12, TR 13, and TR 14 to your teacher as part of your Lesson 3 Assignment in the Module 1 Assignment Booklet.

Reflect and Connect

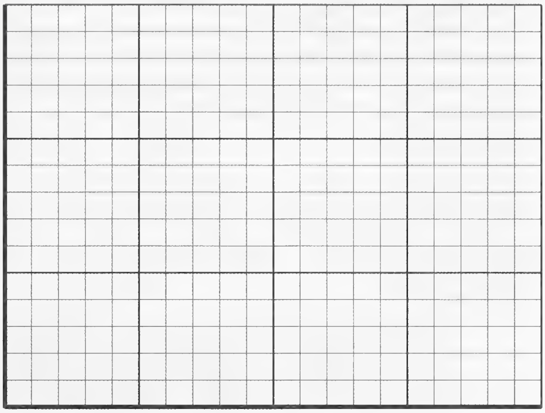
Graphs can be used to tell the story of motion, including the motion of an athlete. Consider the following scenario.

TR 12. Marly is sprint cycling and gets off to a good start, pedalling at a rate of 12.0 m/s for 10.0 s. She tires and slows down to 9.80 m/s for the next 16.0 s. When she gets close to the finish line, she begins pedalling at 11.5 m/s for the next 2.0 s. Sketch her position-time graph and velocity-time graph.

Position-Time Graph



Velocity-Time Graph



TR 13. Marly's competitor, Michelle, starts the race at the same position and same time as Marly. However, she has a different strategy. Michelle pedals at a rate of 8.0 m/s for 8.0 s. She then speeds up to 15.0 m/s for the next 14.0 s. When she gets close to the finish line, she is tired and can only pedal at 10.0 m/s for the last 2.6 s. Sketch her position-time graph over top of Marly's position-time graph.

TR 14. Come to the discussion area ready to share and discuss your graphs. Also, be prepared to discuss how you would determine where and when the two cyclists would meet and which strategy worked best if the race was only 250 m long.

Self-Check

SC 12. Go to page 65 of your textbook and complete question 3 of "Chapter 1 Review." Note the units used in question 3(b), and make sure they are converted similar to "Example 1.2(b)" on page 15 of your textbook.

SC 13. Go to page 65 of your textbook and complete question 4 of the "Chapter 1 Review." Note carefully the units, and make sure they are converted similar to "Example 1.2(b)" on page 15 of your textbook.

SC 14. Go to page 65 of your textbook and complete question 6 of "Chapter 1 Review."

SC 15. Go to page 66 of your textbook and complete question 15 of "Chapter 1 Review."

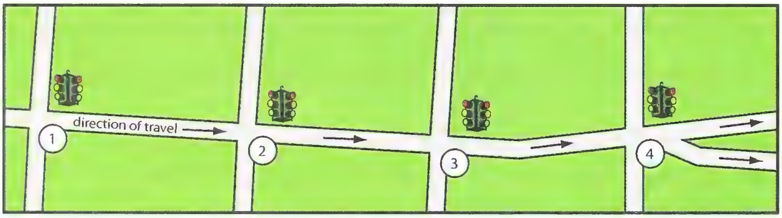
Check your work with the answer in the appendix.

Discuss

Traffic-light synchronization is used in city planning as a way to alleviate traffic congestion and increase flow during peak travelling times. When four lights are synchronized, for example, a driver starting at traffic light 1 and travelling at the posted speed limit should arrive at each intersection as the light is turning green. Each light should be green for the amount of time it takes a driver to pass through all four intersections at the posted speed limit.

© Andrew Park/shutterstock

Prepare to discuss how to use a graphical method to determine the timing sequence of four traffic lights. You can use the lights shown below as a starting point for the discussion. Each intersection is separated by 200 m, and the speed limit is 60 km/h.



Reflect on the Big Picture

In this lesson you saw how graphs can assist you as you describe how objects are moving. The phrase "a picture is worth a thousand words" might well be used to summarize what you experienced. Did you find it helpful to see graphs used to explain motion in problems? Did you find that this lesson was much more densely packed with ideas than the first two?

To help you reflect on your learning experience in this lesson, complete at least one of these three activities:

- Poets and writers have to be very concise in their work. Create a paragraph, words to a song, or a poem that reflects your understanding of motion, graphs, and storytelling.

- What do you think you learned in this lesson? Look over the lesson, and fill in a learning log like the one that follows.

Learning Log
Describe things that you know now that you didn't know before.
Describe things that you still need to work on.
Describe ways to increase your skills and knowledge.

- Choose a type of graph to illustrate your own story. This could be an expression of your day, your life, or a significant event. Once it is graphed, can you support your story through mathematics? Prepare your graph for presentation in the discussion area.

Store your completed reflection in your Physics 20 course folder.

Module 1: Lesson 3 Assignment

Ensure that you have completed all of the questions in the Lesson 3 Assignment. Contact your teacher to find out if you should submit your assignment now or wait until you have completed the Module 1 Assignment Booklet.

Add to the KWL chart you worked on in Lesson 1 and 2. Continue to store your chart in your Physics 20 course folder.

Lesson Summary

There were five parts to the lesson. Each part had an essential question for you to answer.
- Part 1: How can you interpret position-time graphs for motion in one dimension?
- Part 2: How do you determine velocity using a position-time graph?
- Part 3: How can you compare observed motions with position-time graphs?
- Part 4: How can you interpret velocity-time graphs for motion in one dimension?
- Part 5: How do you determine displacement using a velocity-time graph?

Position-time graphs can be used to describe, compare, and interpret uniform motion. On a position-time graph, the data points indicate the position of an object and can be used to determine its displacement in a given time interval. The slope of the line on a position-time graph describes the object's velocity during a given time interval and can be used to produce a velocity-time graph. In turn, the area of a velocity-time graph illustrates the displacement of a moving object.

Lesson Glossary

one-dimensional motion: motion in a straight line

position-time graph: a graph showing the position of an object at varying times, where time is the independent variable and position is the dependent variable

uniform motion: motion at constant speed in a straight line

velocity-time graph: a graph showing the velocity of an object at varying times, where time is the independent variable and velocity is the dependent variable

Lesson 4—Graphical Analysis of Accelerated Motion

Get Focused

"T-minus 5, 4, 3, 2, 1. We have a 'go' for main engine ignition." This is the familiar conversation you hear from mission control when you watch a shuttle launch on television. What you don't hear is exactly how the shuttle—with a mass of more than 70 000 kg, depending on the payload—will achieve a speed of roughly 7600 m/s in less than 9 minutes after main engine ignition. Here is the sequence of events that occurs during the launch.

- Shuttle engines start at 100% of their maximum power, creating a combined maximum thrust of more than 4 million N.
- The shuttle engines are throttled back to around 64% of maximum power shortly after liftoff in order to keep the atmospheric pressure on the shuttle low as it climbs through the dense lower atmosphere.
- After climbing 10 668 m at a speed of 3413 m/s, the engines' power is increased to near 100% again.
- In the last minute of the launch, the engine power is reduced to keep the acceleration of the shuttle at a rate no more than three times that of gravity (29.43 m/s^2) as it leaves Earth's upper atmosphere.

© Dennis Sabo/shutterstock

It's an incredible ride, for sure, and one that needs to be accurately understood so that it can be accomplished safely. From basic data about position, how can you illustrate and determine the velocity and acceleration of a vehicle, such as the shuttle during launch?

In this lesson and the accompanying lab activities you will describe and compare one-dimensional, **accelerated motion** using position-time, velocity-time, and **acceleration-time graphs**. Using **slope** and **area** calculations, you will be able to generate data and solve problems related to accelerated motion.

There are two general problems to solve in the lab activities:

- How are position-time, velocity-time, and acceleration-time graphs related by slope?
- How are position-time, velocity-time, and acceleration-time graphs related by area?

accelerated motion: motion of an object that is either increasing or decreasing in speed or changing direction

acceleration-time graph: a graph showing the acceleration of an object at varying times, where time is the independent variable and acceleration is the dependent variable

slope: a measure of the steepness of a curve

area: a quantity specifying the size of a region

Module 1: Lesson 4 Assignments

Your teacher-marked Lesson 4 Assignment requires you to submit a response to the following:

- Lab—LAB 1, LAB 2, LAB 3, LAB 4, LAB 5, LAB 6, LAB 8, LAB 11, and LAB 12
- Try This—TR 1and TR 2

You must decide what to do with the questions that are not marked by your teacher.

Remember that these other questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

Watch and Listen

Go to your Physics 20 Multimedia DVD, and watch the "Accelerated Motion" animation showing graphs of a space launch. Look for the similarities and differences in the three graphs describing the same motion in different terms.

Self-Check

SC 1. Describe the graph lines depicting uniform acceleration shown in the Accelerated Motion animation.

a. position-time graph
b. velocity-time graph
c. acceleration-time graph

Check your work with the answer in the appendix.

Lesson 4 Lab: Slope and Position-Time, Velocity-Time, and Acceleration-Time Graphs

The launch of a space shuttle is an example of non-uniform (accelerated) motion. Graphical analysis of the shuttle's position with respect to time will reveal the relationships between position, velocity, and acceleration.

© Mike Brown/Dreamstime

The simulation used for this lab lets you specify motions and construct position-time, velocity-time, and acceleration-time graphs. You can learn more about the simulation by reading the Show Me found at the top of the simulation screen.

Problem

How are position-time, velocity-time, and acceleration-time graphs related by slope?

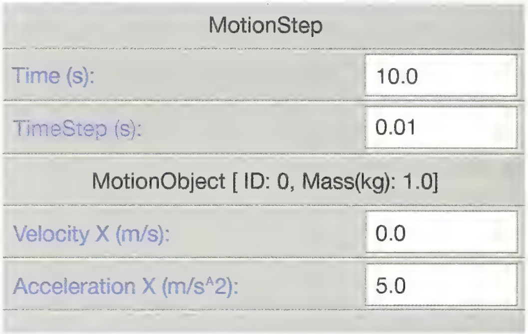
Go to **www.learnalberta.ca**. You may be required to input a username and password. Contact your teacher for this information. Enter the search terms "uniform motion builder" in the search bar. Choose the item called "1D Non-Uniform Motion Builder Graphing (pos, vel, acc) (Grade 11)" from the list. Open the simulation. If you cannot see the Play and Pause buttons on the bottom of the page, you may need to adjust the window. Click on the coloured title bar at the top, and drag the window to the upper right-hand corner of your screen. Then expand the window down by holding your cursor on the bottom border, clicking on the double-headed arrow that appears and dragging it down till you clearly see the bottom buttons. You can adjust the side margins in a similar way to remove the unused black areas. It will be convenient to have this window tight to the right side of your screen. After these adjustments, continue with the procedure.

Procedure

Use the simulation to generate a position-time graph for the shuttle launch, which is initially at rest (v = 0.0 m/s) and accelerates at 5.0 m/s^2 for 10.0 s.

Step 1: Click "Reset" ( ), and then "Add" ( ) to add an object.

Step 2: In the "MotionStep EditorDialog" window, enter a time of 10.0 s, an initial velocity of 0.0 m/s, and an acceleration of 5.0 m/s^2. Then click OK.



Step 3: Click "Play" ( ), and watch the moving object ( ) accelerate.

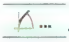
Step 4: To view the position-time graph, do the following:

- Click "Graph." 

- Set "Horizontal Axis" to "Time" by clicking on the down arrow on the right of the horizontal axis box. Then move the slider on the right up to see "Time" and click on it. 

- Set "Vert. Axis" to position by choosing "x0". 

- Click "Fit Graph to the Screen." 

Step 5: To view the slope, expand the graph window by dragging the margin to the right with the double-headed arrow as described earlier till you see the "Slope Mode" button, .

Click this "Slope Mode" button. Click and hold the mouse cursor over the graph line, and the slope value (m/s) will be indicated under Output. You can expand the graph down by dragging the bottom border of the window down and then dragging down the line under the "Zoom Out" button. You can also use the arrows under the "Zoom In" button, but the size adjustment is not as flexible.

Verify that your graph is similar to Figure 1. The slope value is displayed under Output and represents the shuttle's **instantaneous velocity** at the selected time. For example, Figure 1 shows an instantaneous velocity of +25.0 m/s at 5.0 s.

instantaneous velocity: the velocity of an object at an instant of time; the slope of the tangent line to the position-time graph for the selected time

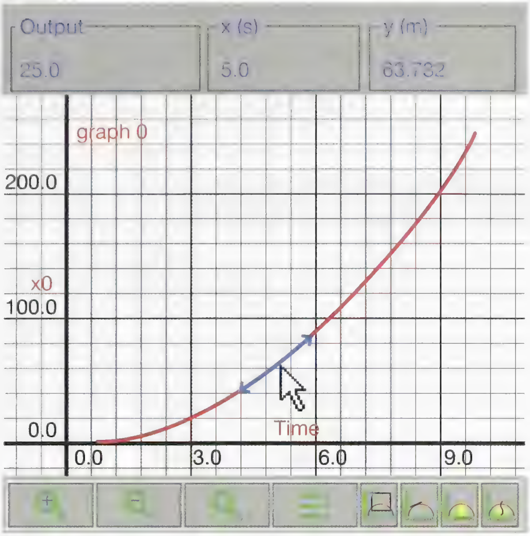


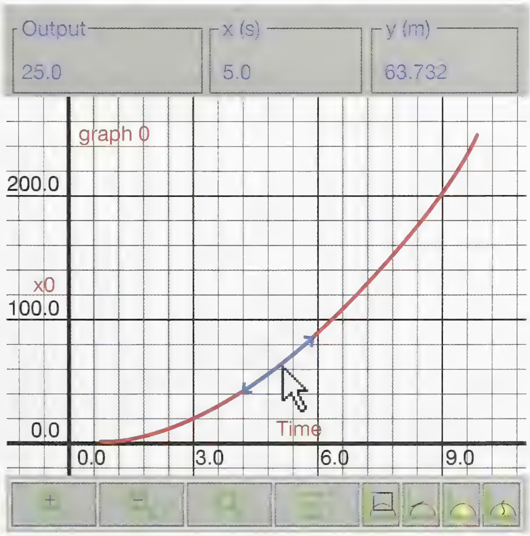
Figure 1

Observation and Analysis

Module 1: Lesson 4 Assignment

Remember to submit the answers to LAB 1, LAB 2, LAB 3, LAB 4, LAB 5, and LAB 6 to your teacher as part of your Lesson 4 Assignment in the Module 1 Assignment Booklet.

LAB 1. Explain how you can tell that the motion of the shuttle is speeding up. In your explanation, refer to the term *slope*.

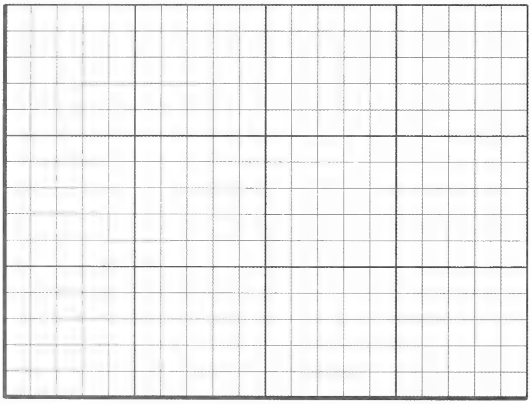


LAB 2. Use the position-time graph to complete the following tasks.

a. Complete the following table. (Click the "Slope Mode" button, , and put your cursor on the exact time value on the graph line for the point you wish to examine. The time value is displayed at the top under the x (s). The velocity will be displayed under Output.)

Time (s)	Velocity (slope) m/s
0	
2	
4	
6	
8	

b. Using the velocity data collect in LAB 2.a., complete a velocity-time graph for the space shuttle launch.



LAB 3. Which of the following best describes the shuttle launch velocity-time graph?

A. The graph is constant and of the mathematical form $y = b$, where b is a constant.

B. The graph is linear and of the mathematical form $y = mx + b$, where b is a constant and m is the slope.

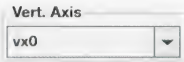
C. The graph is a quadratic curve and of the form $y = ax^2 + bx + c$, where a, b, and c are coefficients.

LAB 4. Write an equation expressing the relation between velocity and time.

It is clear from the previous exercises that the velocity of the shuttle discussed above is not constant. The velocity is continuously changing from a value of 0.0 m/s to a value of 40.0 m/s after 8.0 s. There is clear evidence that the shuttle is accelerating.

LAB 5. Use the simulation to create a velocity-time graph based on the same time, velocity, and acceleration values that were entered in the procedure.

- Change the vertical axis ("Vert Axis") to show velocity ("vx0").



- Click "Fit Graph to the Screen."

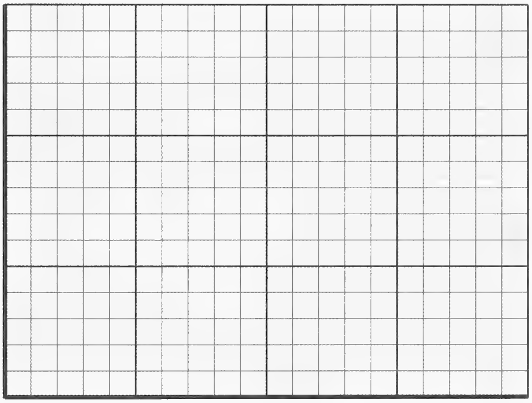
- Verify that this graph is identical to the velocity-time graph you created in LAB 2.

a. Calculate the slope mathematically, and verify your answer using the slope tool on the simulation.

b. What are the units that correctly describe the slope of a velocity-time graph? (**Hint:** Make sure you put the units into your calculation in LAB 5.a. and that you computed them.)

c. What does the slope on a velocity-time graph mean? That is, what quantity of motion does the slope measure?

LAB 6. Use the simulation to create an acceleration-time graph based on the same time, velocity, and acceleration values that were entered in the procedure.



- Change the vertical axis ("Vert. Axis") to show acceleration ("ax0").

- Click "Fit Graph to the Screen."

a. Complete an acceleration-time graph.

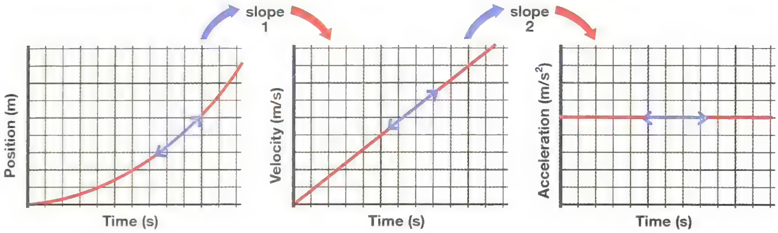
b. In LAB 5 you determined the slope of the velocity-time graph for the shuttle launch. Where or how does that "appear" on the acceleration-time graph?

c. Is the slope of graph 2 equal to zero? What does this mean?

Lab Summary

How are position-time, velocity-time, and acceleration-time graphs related by slope?

The slope of a position-time graph describes velocity.
The slope of a velocity-time graph describes acceleration.



Read

Read "Velocity-time Graphs: Uniform and Non-uniform Motion" on pages 21 to 24 of the textbook. Look for how directions are handled and the formulas and symbols used to solve the problems.

Self-Check

SC 2. How is the slope of a velocity-time graph of uniform motion different than the slope of a velocity-time graph of **non-uniform motion**?

non-uniform motion: motion that is not at a constant speed in a straight line

SC 3. Go to page 30 of your textbook and complete question 2 of "1.3 Check and Reflect."

Check your work with the answer in the appendix.

Read

Read "Instantaneous Velocity" on pages 24 and 25 of the textbook.

Self-Check

SC 4. What does the slope of the tangent to a curved position-time graph give you?

Check your work with the answer in the appendix.

Read

Read "Using Slopes of Position-time Graphs to draw Velocity-time Graphs" on pages 25 to 28 of the textbook. Look for how directions are indicated by positive and negative signs. Note the formulas and symbols used to solve the problems.

Self-Check

SC 5. Go to page 30 of your textbook and complete question 3 of "1.3 Check and Reflect." Note that these are velocity-time graphs.

Check your work with the answer in the appendix.

Read

Read "Negative Acceleration Does Not Necessarily Mean Slowing Down" on pages 28 and 29 of the textbook. Look for the answer to the following Self-Check question.

Self-Check

SC 6. Under what circumstances could an object have a negative acceleration and not be slowing down?

Check your work with the answer in the appendix.

Lesson 4 Lab: Area and Position-Time, Velocity-Time, and Acceleration-Time Graphs

Now you will explore the idea that area is a measure of the total or cumulative change in some variable. The variables will include position, velocity, and acceleration. In this case, you will base your data analysis on an object that falls under the influence of gravity, such as the apple that may or may not have landed on Newton's head.

The simulation used for this lab lets you specify motions and construct position-time, velocity-time, and acceleration-time graphs. You can learn more about the simulation by reading the Show Me found at the top of the simulation screen.

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Problem

How are position-time, velocity-time, and acceleration-time graphs related by area?

Go to **www.learnalberta.ca**, and re-open the "1D Non-Uniform Motion Builder Graphing (pos, vel, acc)" simulation. Adjust the screen as you have done previously, if needed. Then continue with the procedure.

Procedure

Use the simulation to generate an acceleration-time graph for an apple falling from rest ($v = 0.0$ m/s) for 5.0 s.

Step 1: Clear all objects by selecting them and clicking "Remove" ( ).

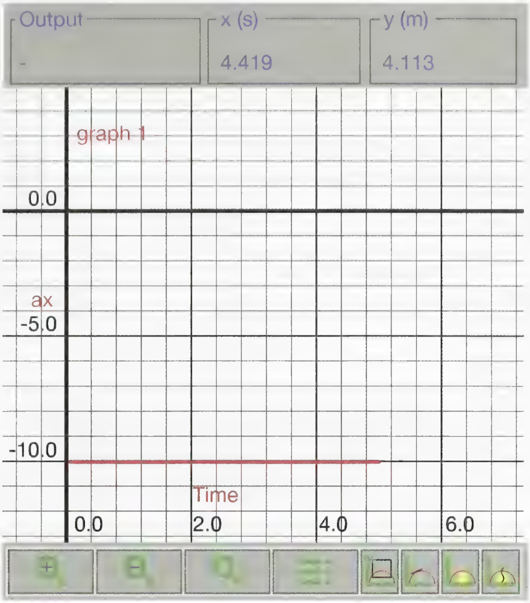
Step 2: Click "Reset" ( ) and then "Add" ( ) to add an object.

Step 3: In the "MotionStep EditorDialog" window, enter a time of 5.0 s, an initial velocity of 0.0 m/s, and an acceleration of -9.81 m/s^2. Click "OK."

Step 4: Click "Play" ( ), and watch the moving object ( ) accelerate.

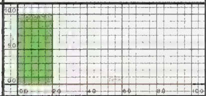
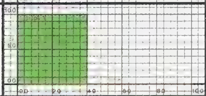
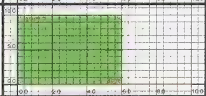
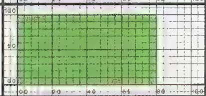
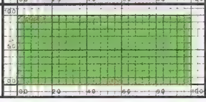
Step 5: Generate an acceleration-time graph by first clicking on the "Graph" button (Graph). This will open the Motion Grapher. Set the horizontal axis to time. (Remember to click the down arrow, move the slider up, and click "Time".) Set the vertical axis to accelerator "ax0"(Vert. Axis ax0). Finally, click "Fit Graph to the Screen" (Fit Graph to the Screen).

Step 6: Verify that your graph is similar to the following acceleration-time graph. Note how the graph line is below the 0.0 axis line because it is a negative acceleration.



Observation and Analysis

LAB 7. Using the "Integrate the Selected Graph" tool, sweep out the area from left to right between $t = 0.0$ s and each of the following times to complete the table.

Time (s)	Area Image	Area (Output)
1.0		________
2.0		________
3.0		________
4.0		________
5.0		________

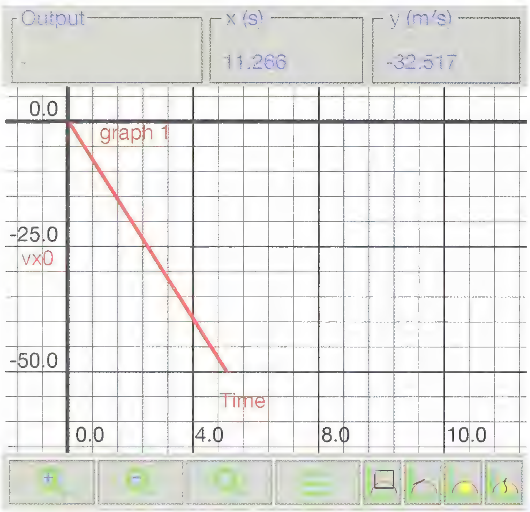
Module 1: Lesson 4 Assignment

Remember to submit the answer to LAB 8 to your teacher as part of your Lesson 4 Assignment in the Module 1 Assignment Booklet.

LAB 8. Each of the measured areas is a rectangle. You will recall that the area of a rectangle is calculated as length × height.

a. What are the units of length for each rectangle?
b. What are the units of height for each rectangle?
c. Multiply the units of length and height to determine the units of area for each rectangle. What variable is the area describing?

LAB 9. Using the simulation, create a velocity-time graph for the falling apple described in the procedure by doing the following:



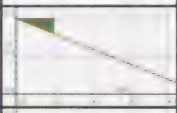
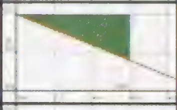
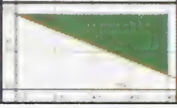
- Change “Vert. Axis” to show velocity (“vx0”). 

- Click “Fit Graph to the Screen.” 

Verify that your graph is similar to the velocity-time graph shown.

LAB 10.

Using the "Integrate the Selected Graph" tool, ( ), sweep out the area from left to right between $t = 0.0$ s and each of the following times to complete the table.

Time (s)	Area Image	Area (Output)
1.0		________
2.0		________
3.0		________
4.0		________

Module 1: Lesson 4 Assignment

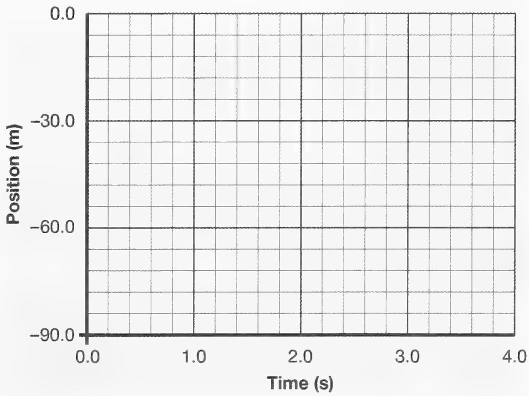
Remember to submit the answers to LAB 11 and LAB 12 to your teacher as part of your Lesson 4 Assignment in your Module 1 Assignment Booklet.

LAB 11. Each measured area is a triangle. The calculation of the area of a triangle is ½ length × height.

a. What are the units of length for each triangle?
b. What are the units of height for each triangle?
c. Multiply the units of the length (s) by the unit of height (m/s). What variable is the area describing?

LAB 12.

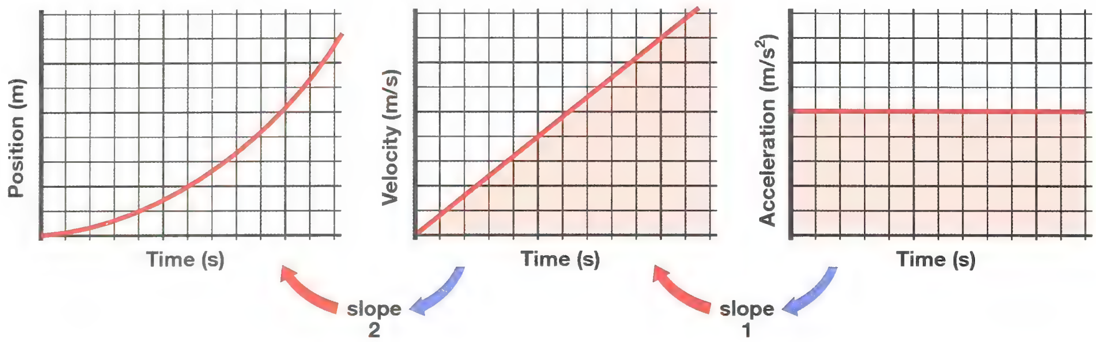
a. Plot the data collected in LAB 10.
b. Explain what this graph shows.
c. Why are all of the positions negative?



Lab Summary

How are position-time, velocity-time, and acceleration-time graphs related by area?

The area of an acceleration-time graph describes velocity.
The area of a velocity-time graph describes displacement.



Read

Read "Analyzing Velocity-time Graphs" on pages 31 to 35 of the textbook to see how the concepts you have just learned are used to solve problems. As you read, cover up the solution and record how you would solve the problem. Then check your answer and method with the solution presented.

Self-Check

SC 7. From a velocity-time graph, explain how you get the

a. displacement
b. acceleration

Check your work with the answer in the appendix.

Read

Read "Example 1.9" on page 40 and "Example 1.10" on pages 41 to 42 of the textbook to see how the acceleration and displacement are numerically calculated from a velocity-time graph.

Self-Check

SC 8. The areas of sections A and C of "Figure 1.46" on page 38 of your textbook were determined using a rectangle and a triangle in "Example 1.9." For each section, draw the rectangle and triangle and give the dimensions.

Check your work with the answer in the appendix.

Read

Read "Example 1.11" on pages 43 and 44 of the textbook to see how a position-time graph is drawn from a velocity-time graph.

Self-Check

SC 9. Go to page 44 of your textbook and complete question 7 of "1.4 Check and Reflect."

SC 10. Go to page 45 of your textbook and complete question 18 of "1.4 Check and Reflect."

Check your work with the answer in the appendix.

Module 1: Lesson 4 Assignment

Remember to submit the answers to TR 1 and TR 2 to your teacher as part of your Lesson 4 Assignment in the Module 1 Assignment Booklet.

Try This

In some complex motion situations, an object undergoes several different accelerations. Graphical analysis can be used to solve complex problems quickly and easily. Using the graphing capabilities of the "1D Non-Uniform Motion Builder Graphing (pos, vel, acc)" simulation, collect graphical data and verify your answers for the following questions.

TR 1. You are riding in an elevator. Starting from rest, the elevator undergoes the following motions:

- It accelerates from rest ($v = 0.0$ m/s) upwards for 5.0 s at +2.0 m/s^2.
- It then coasts for 20.0 s at 10.0 m/s ($a = 0.0$ m/s^2).
- Finally, starting at 10.0 m/s, it accelerates downward for 2.5 s at –4.00 m/s^2.

a. Complete a position-time graph.

b. Complete a velocity-time graph.

c. Complete an acceleration-time graph.

d. Using the slope of the position-time graph, determine the maximum speed reached by the elevator.

e. Using area, determine how far the elevator travelled while coasting.

f. Using area, determine how far the elevator travelled while accelerating downward.

TR 2. Basam is standing on the edge of a cliff and tosses her physics book upward with a speed of 22.0 m/s. It hits the ground at the base of the cliff 6.0 s later. Use the "1D Non-Uniform Motion Builder Graphing (pos, vel, acc)" simulation to determine how high the cliff is and how fast the book was moving when it landed.

TR 3. Fill in the blanks using the terms *position*, *velocity*, or *acceleration*.

a. A change in position in an interval of time is called ______________.

b. Velocity acting for an interval of time produces a change in ______________.

c. A change in velocity in an interval of time is called ______________.

d. Acceleration acting for an interval of time produces a change in ______________.

Reflect and Connect

The following data table shows the altitude of the shuttle during launch. Use this data and your graphing skills to illustrate the vertical velocity and acceleration of the vehicle in the first minute and one-half of the launch. In other words, draw a position-time graph. From that, draw the velocity-time graph. Use the velocity-time graph to draw the acceleration-time graph.

Time (s)	Altitude (m)
0	0
10	560
20	2240
30	5040
40	8960
50	14 000
60	20 160
70	27 440
80	35 840
90	45 360

Can you connect this with how it must have felt to have been in the shuttle at these different times? What would have been the most exciting point during liftoff? Why?

Discuss

Prepare to share and compare your shuttle altitude and experience graphs with others. Use this question as a starting point for discussion: Where would the best thrill point or extreme experience be during the liftoff?

Going Beyond

You are programming a control computer for a subway train with the following parameters.

- The train can accelerate from rest ($v = 0.0$ m/s) at 2.00 m/s^2.
- The maximum speed of the train is 30.0 m/s.
- The train can brake at 3.00 m/s^2.
- The total distance that the subway car travels between stops is 1.0 km.

© Image courtesy of Shutterstock.com

Try This

TR 4. Use the following questions and the graphing capabilities of the simulation to help create motion scripts that could accomplish this.

a. How much time is required to accelerate from rest at 2.00 m/s^2 in order to achieve the maximum speed?

b. How far does the subway train travel while accelerating up to the maximum speed?

c. How long will it take the train to stop if it starts at the maximum speed and accelerates at 3.00 m/s^2?

d. How far does the subway train travel while stopping?

e. Given the starting and stopping distances, how far and how long does the train travel at the maximum speed? (**Hint:** Use the answers for TR 4.b. and TR 4.d. to help you answer the question.)

f. How much time will it take for the subway train to travel between stops?

g. What is the average speed of the train as it travels between stops?

h. Give the three motion scripts that will be used to control the train.

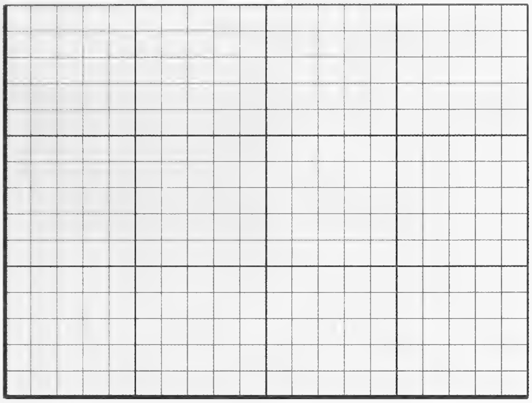
time: ______ s, initial velocity: ______ m/s, acceleration: ______ m/s^2

time: ______ s, initial velocity: ______ m/s, acceleration: ______ m/s^2

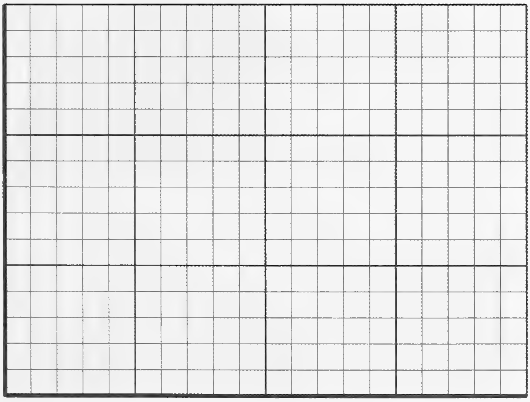
time: ______ s, initial velocity: ______ m/s, acceleration: ______ m/s^2

i. Complete all three graphs that illustrate the train's motion.

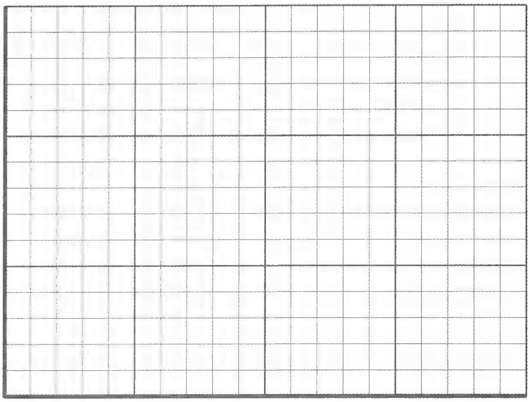
Position-Time



Velocity-Time



i. **Acceleration-Time**



Reflect on the Big Picture

In this lesson you saw again how graphs assist you as you try to describe how objects are moving. You used graphs and some of their features to solve problems. Did you see how the concepts here built on the ideas from the first lessons?

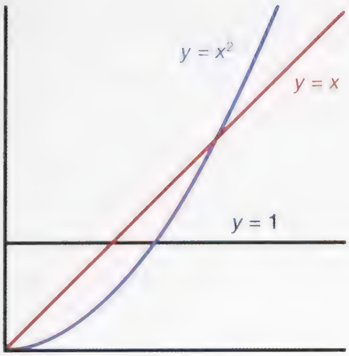
To help you reflect on your learning experience in this lesson, complete at least one of these three activities:

- The accelerated motion you have just experienced through the shuttle-launch example is an extreme example of great power propelling an object. Can you use your shuttle-launch graph as a basis for illustrating the emotional and physical impacts of accelerated motion? This could be a collage, drawing, or descriptive paragraph.
- Create a comic strip where a cartoon character expresses the concepts of slope, area, acceleration, and velocity. Identify the different types of motion, and compare and contrast motion.
- Map the concepts and terms in this lesson. Ensure that it describes in your words how the items relate to the description and understanding of motion.

Store your completed reflection in your Physics 20 course portfolio.

Going Beyond

While you were working with the Motion Builder simulation, you saw graphs that were similar to the following.



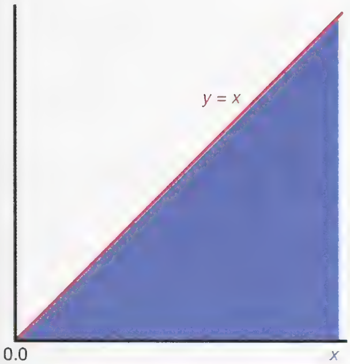
$y = 1$ (when there was constant acceleration)

$y = x$ (velocity when there is constant acceleration)

$y = ½ x^2$ (displacement when there is constant acceleration)

Can you guess what function would give the area shown in red?

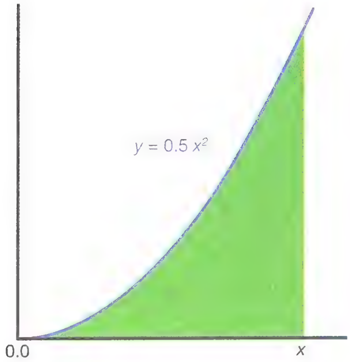
Would it be $y = 1$, $y = x$, or $y = ½ x^2$?



Can you guess what function would give the area shown in blue?

Would it be $y = 1$, $y = x$, or $y = ½ x^2$?

You likely found it easy to find the red area and the blue area. You've known how to find the area of rectangles and triangles for years. (The red area is $y = x$; the blue area is $y = ½ x^2$.)

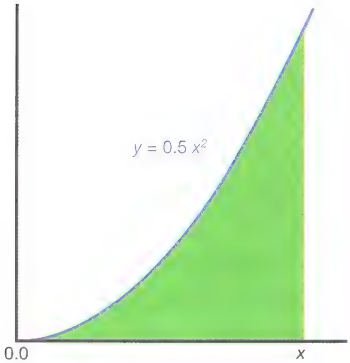


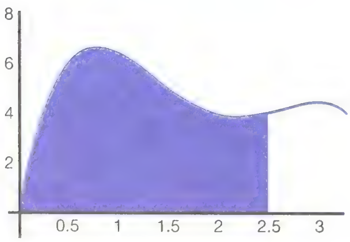
Here is a harder question. What is the area shown in green?

There are no rectangles or triangles to use. So what can you do?

Since someone must have figured this out before, a good first step would be to do some rapid research. You could search the Internet for "area under x squared" and see what you find.

You might also consider the sequence $y = 1$, $y = ½\,x^2$, . . . and try to ascertain the next term. Both of these methods would likely lead you to $y = \frac{1}{6}x^3$.





If you are looking for a definite area, such as the ones shown to the left, there are some statistical computer methods that can help.

Quite often you don't need an exact answer; you just need a close approximation. One numerical way of finding an approximate area is using Monte Carlo Integration. It's a lot like throwing darts randomly at a board. You count the ones that hit the area you're interested in. The ratio of the hits to the total lets you find the area.

The "Monte Carlo Area" applet, found on the Physics 20 Multimedia DVD, lets you try this out. Watch out if you have a slower computer—it can take a long time to plot 1 000 000 points. The number of points to try is up to you, but 1000 should work fairly well for everyone.

If you are interested in how the applet works, you can check out the source code on the Physics 20 Multimedia DVD. Choose the item called "Monte Carlo Source Code." Finding the area is done in the function gwasplot.

Module 1: Lesson 4 Assignment

Ensure that you have completed all of the questions in the Lesson 4 Assignment. Contact your teacher to find out if you should submit your assignment now or wait until you have completed the Module 1 Assignment Booklet.

Add to the KWL chart you worked on in Lessons 1 to 3. Continue to store your chart in your Physics 20 course folder.

Lesson Summary

There were two general problems to solve in this lesson:

- How are position-time, velocity-time, and acceleration-time graphs related by slope?
- How are position-time, velocity-time, and acceleration-time graphs related by area?

Position-time, velocity-time, and acceleration-time graphs can be used to describe, compare, and interpret accelerated motion. The following slope and **area relationships** can be used to solve complex problems and describe accelerated motion.

area relationship: used to find velocity from an acceleration-time graph or displacement from a velocity-time graph

- The slope of a position-time graph is a measure of instantaneous velocity.
- The slope of a velocity-time graph is a measure of instantaneous acceleration.
- The area of an acceleration-time graph is a measure of the total change in velocity.
- The area of a velocity-time graph is a measure of the total change in position.

Lesson Glossary

accelerated motion: motion of an object that is either increasing or decreasing in speed or changing direction

acceleration-time graph: a graph showing the acceleration of an object at varying times, where time is the independent variable and acceleration is the dependent variable

area: a quantity specifying the size of a region

area relationships: used to find velocity from an acceleration-time graph or displacement from a velocity-time graph

instantaneous velocity: the velocity of an object at an instant of time; the slope of the tangent line to the position-time graph for the selected time

non-uniform motion: motion that is not at a constant speed in a straight line

slope: a measure of the steepness of a curve

Lesson 5—Kinematics Equations Describe Acceleration, Displacement, and Velocity

Get Focused

At 4:02 p.m. (EDT) on Tuesday, August 2, 2005, Air France Flight 358 landed on runway 24 at the Pearson International Airport in Toronto. It had been circling the airport in a heavy thunderstorm. Within 20 minutes, passengers from this aircraft appeared on Highway 401 near the airport, flagging down drivers and claiming to be the victims of a plane crash.

It was later revealed that the plane failed to stop before the end of the runway. The fuselage ended up in a creek bed, engulfed in flames. What had happened? Was the runway too short? Did the plane's braking system fail? What role did the weather play?

© CTV News

Detailed information must be used to determine takeoff and landing distances for each type of commercial and passenger plane. Runway lengths are based on the relationships between the initial velocity, final velocity, and acceleration of the aircraft. To do this, investigators use a set of equations to help solve acceleration, velocity, and displacement problems.

Which equations do they use, and how do they use them? You will determine this as you investigate, derive, and apply **kinematic** equations to solve complex problems involving applications of constant acceleration.

kinematics: the study of motion without concern for forces, masses, or energy

In this lesson you will explore the following essential questions:

- Which equations are useful in solving acceleration, velocity, and displacement problems?
- Where do these equations come from?

As you work through this lesson, you will find it useful to recall the following facts that you should already know about describing motion graphically from your work in Lessons 3 and 4.

- Displacement-time graphs have a slope that indicates the object's velocity.
- For uniform acceleration, the velocity-time graph has a slope that indicates the object's acceleration.
- Instantaneous velocity can be found using a tangent on the position-time graph for an object undergoing accelerated motion in a straight line.
- The area under the curve of a velocity-time graph is equal to the object's displacement.

If you are unsure or need to review any of these concepts, look back at Lessons 3 and 4 or read pages 11 and 12, 24 to 26, and 31 to 34 in your textbook.

Module 1: Lesson 5 Assignments

Your teacher-marked Lesson 5 Assignment requires you to submit a response to the following:
- Try This—TR 1, TR 2, TR 3, and TR 4
- Lab—LAB 1, LAB 2, LAB 3, LAB 4, and LAB 5

You must decide what to do with the questions that are not marked by your teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

In previous lessons you used graphs to assist in analyzing the motion of objects. In simple cases, this is all you need. You've seen that graphical analysis is a powerful tool. When used to solve complex motion problems involving acceleration, velocity, and displacement, graphing often takes too long and is prone to error. Using equations can help with these problems, so you will now investigate some equations that are useful in problem solving.

Equations Involving Acceleration, Velocity, and Displacement

To begin, recall the basic equations that describe average velocity and acceleration.

$$\vec{v}_{\text{ave}} = \frac{\Delta \vec{d}}{\Delta t} \qquad \vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

Using only these two equations and some graphical analysis, several other useful equations have been derived for solving problems involving acceleration, velocity, and displacement. You will learn more about these equations and how they are used in the Watch and Listen and as they are used in the sample solutions provided.

Watch and Listen

There are six equations for motion. You can view their derivation in the item called "Derivation of Equations" on the Physics 20 Multimedia DVD.

Here are the six kinematic equations for motion:

Equation 1

$$\vec{v}_{\text{ave}} = \frac{\Delta\vec{d}}{\Delta t}$$

Equation 2

$$\Delta\vec{d} = \vec{v}_{\text{i}}\Delta t + \tfrac{1}{2}\,\vec{a}(\Delta t)^2$$

Equation 3

$$\Delta\vec{d} = \left(\frac{\vec{v}_{\text{f}} + \vec{v}_{\text{i}}}{2}\right)\Delta t$$

Equation 4

$$\vec{a} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}$$

Equation 5

$$\Delta\vec{d} = \vec{v}_{\text{f}}\Delta t - \tfrac{1}{2}\,\vec{a}(\Delta t)^2$$

Equation 6

$$v_{\text{f}}^2 = v_{\text{i}}^2 + 2a\Delta d$$

Note that equation 1, $\vec{v}_{\text{ave}} = \frac{\Delta\vec{d}}{\Delta t}$, may be used for both uniform and non-uniform motion.

Equations 2 to 6 are only used when the object is undergoing uniformly accelerated motion such as when it is subjected to constant acceleration.

In the equations above,

- $\vec{v}_{\text{ave}}$ is average velocity.
- $\vec{v}_{\text{f}}$ is the final velocity.
- $\vec{a}$ is the acceleration.
- $\vec{v}_{\text{i}}$ is initial velocity.
- $\Delta\vec{d}$ is the displacement.
- Δt is the time interval.

Now that you have identified these six equations and when they can be used, how do you approach problem solving using these equations?

A Problem-Solving Method

Use the GRASP method (acronym for **G**iven, **R**equired, **A**nalysis, **S**olution, **P**araphrase) that you have seen in the previous lessons in solving kinematic problems with equations:

- Given: Read the question. Identify and write down the known variables. Make a diagram, if needed, to keep everything straight.
- Required: From the question, extract and write down what is being asked for (the unknown variable).
- Analysis: Decide how to best solve for the required quantity. Select and write down the equation that contains the variables listed. (It does not matter what order the variables are in or which one is unknown.) Specify the positive direction, if needed.
- Solution: Manipulate the equation, if necessary, so that the unknown is isolated.

- Substitute in the known variables along with their units.
- Solve for the answer.
- Remember to include units and direction, where appropriate (i.e., vector quantities). Round the final answer to the correct number of significant digits, consistent with the rules on page 877 of the textbook.
- Paraphrase: Answer the question in a proper English sentence.

The following series of examples demonstrates this method. Reference these examples as you work on the Try This questions for your Lesson 5 Assignment.

Example Problem 1: A quad travelling at +10.0 m/s accelerates until the final velocity becomes +20.0 m/s. If the time interval was 5.0 s, determine the quad's displacement.

© sculpies/shutterstock
A quad is in motion.

Given (Known Variables)	$\vec{v}_i = +10.0 \text{ m/s}$ $\vec{v}_f = +20.0 \text{ m/s}$ $\Delta t = 5.0 \text{ s}$
Required (Unknown Variable)	the displacement ($\Delta\vec{d}$)
Analysis	The equation that uses all the variables is $\Delta\vec{d} = \left(\dfrac{\vec{v}_f + \vec{v}_i}{2}\right)\Delta t$.
Solution	$\Delta\vec{d} = \left(\dfrac{(+10.0 \text{ m/s}) + (+20.0\text{m.s})}{2}\right)(5.0 \text{ s})$ $= +75 \text{ m}$, correct to 2 significant digits
Paraphrase	The displacement of the quad is +75 m.

Self-Check

SC 1. Go to page 53 of your textbook and complete question 6 of "1.5 Check and Reflect."

Check your work with the answer in the appendix.

Read

Read "Example 1.12" on page 47 of your textbook to see an example of manipulating the equation to isolate the unknown variable. If you feel comfortable manipulating variables, cover the solution to "Example 1.12" and calculate the answer. Then check your work.

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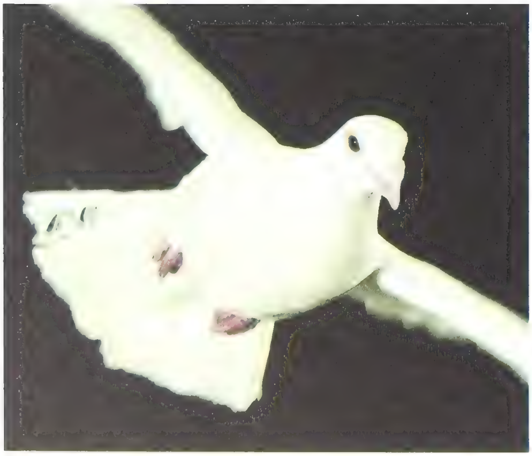
Self-Check

SC 2. Solve practice problem 2 for "Example 1.12" on page 47 of your textbook.

Check your work with the answer in the appendix.

Module 1: Lesson 5 Assignment

Remember to submit the answer to TR 1 to your teacher as part of your Lesson 5 Assignment in the Module 1 Assignment Booklet.



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Try This

TR 1. A homing pigeon starts from rest and accelerates uniformly at $+4.00\ \text{m/s}^2$ for 10.0 s. What is the velocity after the acceleration?

Example Problem 2: A car starts from rest and accelerates at +5.0 m/s^2 until it has travelled +250 m. What is the time interval?

Given (Known Variables)	$\vec{v}_i = 0.0$ m/s $\vec{a} = +5.0$ m/s^2 $\Delta\vec{d} = +250$ m
Required (Unknown Variable)	the time interval (Δt)
Analysis	The equation that uses all the variables is $\Delta\vec{d} = \vec{v}_i\Delta t + 1/2\,\vec{a}(\Delta t)^2$. It will have to be manipulated to isolate Δt. Since $\vec{v}_i$ = 0.0 m/s, the equation becomes $\Delta\vec{d} = \frac{1}{2}\vec{a}(\Delta t)^2$.
Solution	$\Delta\vec{d} = 1/2\,\vec{a}(\Delta t)^2$ Now use magnitudes only because you cannot divide vectors. $(\Delta t)^2 = \frac{2\Delta d}{a}$ $\Delta t = \sqrt{\frac{2\Delta d}{a}}$ $\Delta t = \sqrt{\frac{2(250\text{ m})}{5.0\text{ m/s}^2}}$ $\Delta t = 10$ s, correct to 2 significant digits.
Paraphrase	The time interval is 10 s.

Read

Read pages 48 and 49 of your textbook. Note how the GRASP method is used with the equation in "Example 1.13."

Self-Check

SC 3. Solve practice problem 2 for "Example 1.14" on page 50 of your textbook.

Check your work with the answer in the appendix.

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A motorcycle is on the road.

Module 1: Lesson 5 Assignment

Remember to submit the answer to TR 2 to your teacher as part of your Lesson 5 Assignment in the Module 1 Assignment Booklet.

Try This

TR 2. A car has an initial velocity of +30.0 m/s and undergoes an acceleration of –5.00 m/s^2 for 5.00 s.

a. Find the displacement after the acceleration.

b. Find the velocity after the acceleration.

Read

See how another kinematic equation was derived and how it is used to find the answer to a problem by reading the bottom of page 51 and "Example 1.16" on page 52 of your textbook. Cover the solution to "Example 1.16," and calculate the answer. Then check your work.

Example Problem 3: An object accelerates from +5.00 m/s to +100 m/s. If the object travelled +250 m during this time, what was the acceleration?

Given (Known Variables)	$\vec{v}_{\mathrm{i}} = +5.0\ \mathrm{m/s}$ $\vec{v}_{\mathrm{f}} = +100\ \mathrm{m/s}$ $\Delta\vec{d} = +250\ \mathrm{m}$
Required (Unknown Variable)	the acceleration ($\vec{a}$)
Analysis and Solution	The equation containing all the variables is $v_{\mathrm{f}}^2 = v_{\mathrm{i}}^2 + 2a\Delta d$. Manipulate the equation to isolate a. When dividing using vectors, use the scalar form. $a = \dfrac{v_{\mathrm{f}}^2 - v_{\mathrm{i}}^2}{2\Delta d}$ $= \dfrac{(100\ \mathrm{m/s})^2 - (5.0\ \mathrm{m/s})^2}{2(250\ \mathrm{m})}$ $= +20.0\ \mathrm{m/s^2}$
Paraphrase	The acceleration was +20.0 m/s^2.

Example Problem 4: A ball rolls up an inclined plane with an initial upward velocity of +9.00 m/s and stops rolling upward after 3.00 s. Then it begins to roll back down the plane. What was the displacement after 3.00 s?

Given (Known Variables)	$\vec{v}_i = +9.00 \text{ m/s}$ $\vec{v}_f = 0.00 \text{ m/s}$ $\Delta t = 3.00 \text{ s}$
Required (Unknown Variable)	the displacement ($\Delta\vec{d}$)
Analysis and Solution	Choose up the ramp as the positive direction. The equation to use is $\Delta\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right)\Delta t$ $\Delta\vec{d} = \left(\frac{0 + (+9.00 \text{ m/s})}{2}\right)(3.00 \text{ s})$ $= +13.5 \text{ m}$
Paraphrase	The displacement after 3.00 s was +13.5 m.

Module 1: Lesson 5 Assignment

Remember to submit the answers to LAB 1, LAB 2, LAB 3, LAB 4, and LAB 5 to your teacher as part of your Lesson 5 Assignment in the Module 1 Assignment Booklet.

Lesson 5 Lab: Could You Be a Goalie for the NHL?

Complete “1-8 QuickLab: Could You Be a Goalie for the NHL?” on page 57 of your textbook. In step two of the procedure, have the zero end of the ruler just above your hand. In step 6, record where the top of your hand is on the ruler.

LAB 1. Complete steps 1–7 of “Procedure” on page 57 of your textbook. For step 6, you should complete at least three trials. List your trial results.

LAB 2. Answer question 1 on page 57 of your textbook.

LAB 3. Answer question 2 on page 57 of your textbook.

LAB 4. Answer question 3 on page 57 of your textbook.

LAB 5. Answer question 4 on page 57 of your textbook.

Example Problem 5: The driver of a car travelling east at 30.0 m/s applies the brakes to generate an acceleration of 4.00 m/s^2 west. If the final speed of the car was 5.00 m/s east, how far did the car travel in the acceleration period?

Given	$\vec{v}_i = +30.0 \text{ m/s [E]}$ $\vec{v}_f = +5.00 \text{ m/s [E]}$ $\vec{a} = -4.00 \text{ m/s}^2 \text{ [E]}$
Required	the distance travelled (Δd)
Analysis and Solution	Choose east as the positive direction. The equation that contains all the variables is $v_f^2 = v_i^2 + 2a\Delta d$. Manipulate the equation to isolate Δd. When dividing using vectors, use the scalar form. $\Delta d = \frac{v_f^2 - v_i^2}{2a}$ $= \frac{(5.00 \text{ m/s})^2 - (30.0 \text{ m/s})^2}{2(-4.00 \text{ m/s}^2)}$ $= +109 \text{ m}$
Paraphrase	The distance travelled was 109 m.

Self-Check

SC 4. Solve a problem like the investigators of the Air France crash had to grapple with by answering practice problem 1 of "Example 1.16" on page 52 of your textbook.

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An airliner lands on a runway during sunset.

Check your work with the answer in the appendix.

Module 1: Lesson 5 Assignment

Remember to submit the answer to TR 3 to your teacher as part of your Lesson 5 Assignment in the Module 1 Assignment Booklet.

Try This

TR 3. A rocket sled that was initially at rest reaches a final speed of +30.0 m/s over a displacement of +45.0 m.

a. Find the acceleration.
b. Find the time it took to travel the first 45.0 m.

Read

What happens when the acceleration is caused by gravity? Read from the top of page 56 through the end of "Example 1.17" on the top of page 58.

Example Problem 6: How fast will a falling object travel after 7.00 s if it is dropped from rest?

Given	$\vec{v}_i = 0.0$ $\Delta t = 7.00\text{ s}$ $\vec{a} = -9.81\text{ m/s}^2$
Required	the final velocity $(\vec{v}_f)$
Analysis and Solution	Choose the positive direction to be upwards. The equation, that will have to be manipulated to get $\vec{v}_f$, is $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$ $\vec{a}\Delta t = \vec{v}_f - \vec{v}_i$ $\vec{v}_f = \vec{v}_i + \vec{a}\Delta t_i$ = 0.0 + (–9.81 m/s2)(7.00 s) = –68.7 m/s
Paraphrase	The final velocity of the object will be 68.7 m/s downward.

Example Problem 7: A man standing on the roof of a building throws a stone downward at 20.0 m/s. The stone hits the ground after 5.00 s. How tall is the building?

Given	$\vec{v}_{\mathrm{i}} = -20.0\ \mathrm{m/s}$ $\vec{a} = -9.81\ \mathrm{m/s^2}$ $\Delta t = 5.00\ \mathrm{s}$
Required	the height of the building $(\Delta\vec{d}\,)$
Analysis and Solution	Choose the positive direction to be upwards. The distance the stone falls is equal to the height of the building. The equation that contains the variables is $\Delta\vec{d} = \vec{v}_{\mathrm{i}}\Delta t + \frac{1}{2}\,\vec{a}(\Delta t)^2$ $\Delta\vec{d} = (-20.0\ \mathrm{m/s})(5.00\ \mathrm{s}) + \frac{1}{2}(-9.81\ \mathrm{m/s^2})(5.00\ \mathrm{s})^2$ $= -100\ \mathrm{m} + (-123\ \mathrm{m})$ $= -223\ \mathrm{m}$
Paraphrase	The height of the building is 223 m.

Read

Read pages 59 to 61 of your textbook to see examples of problem solving with projectiles directed upwards. Pay careful attention to the analysis for part (a) in both "Example 1.18" and "Example 1.19," and note the equations chosen in both examples in parts (a) and (b).

Self-Check

SC 5. When an object is thrown upwards, what is its final velocity at the maximum height?

SC 6. When an object that is thrown upwards begins to fall back down, what is its initial velocity for the downward path?

Check your work with the answer in the appendix.

Example Problem 8: An object is thrown upward at 49.05 m/s.

- What is the object's velocity at 3.00 s?

Given	$\vec{v}_{\mathrm{i}} = +49.05\ \mathrm{m/s}$ $\vec{a} = -9.81\ \mathrm{m/s^2}$ $\Delta t = 3.00\ \mathrm{s}$

Required	the velocity after 3.00 s ($\vec{v}_f$)
Analysis and Solution	Choose the positive direction to be upward. The equation, which will have to be manipulated to get $\vec{v}_f$, is $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$ $\vec{a}\Delta t = \vec{v}_f - \vec{v}_i$ $\vec{v}_f = \vec{v}_i + \vec{a}\Delta t_i$ = (+49.05 m/s) + (–9.81 m/s2) (3.00 s) = +19.6 m/s
Paraphrase	The velocity at 3.00 s is 19.6 m/s [upward].

- What is the velocity after 7.00 s?

Given	$\vec{v}_i = +49.05$ m/s $\vec{a} = -9.81$ m/s^2 $\Delta t = 7.00$ s
Required	the velocity after 7.00 s ($\vec{v}_f$)
Analysis and Solution	Choose the positive direction to be upward. The equation, which will have to be manipulated to get $\vec{v}_f$, is $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$ $\vec{a}\Delta t = \vec{v}_f - \vec{v}_i$ $\vec{v}_f = \vec{v}_i + \vec{a}\Delta t_i$ = (+49.05 m/s) + (—9.81 m/s2)(7.00 s) = —19.6 m/s
Paraphrase	The velocity at 7.00 s is 19.6 m/s [downward].

- The object momentarily stops moving vertically at the maximum height. How long does it take to reach its maximum height?

Given	$\vec{v}_i = +49.05 \text{ m/s}$ $\vec{a} = -9.81 \text{ m/s}^2$ $\Delta\vec{v}_f = 0.0 \text{ m/s}$
Required	the time to reach its maximum height (Δt)
Analysis and Solution	Choose the positive direction to be upward. The equation, which will have to be manipulated to get Δt, is $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$. Remember, you cannot divide vectors. You can only divide the magnitudes of the vectors. $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$ $\vec{a}\Delta t = \vec{v}_f - \vec{v}_i$ $\Delta t = \frac{\lvert\vec{v}_f\rvert - \lvert\vec{v}_i\rvert}{\vec{a}}$ $= \frac{(0.0 \text{ m/s}) - (+49.05 \text{ m/s})}{-9.81 \text{ m/s}^2}$ $= 5.00 \text{ s}$
Paraphrase	The time to reach its maximum height is 5.00 s.

- What is the maximum displacement?

Given	$\vec{v}_i = +49.05$ m/s $\vec{a} = -9.81$ m/s^2 $\Delta t = 5.00$ s
Required	the maximum displacement ($\Delta\vec{d}$)
Analysis and Solution	Choose the positive direction to be upward. The equation to use is $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$ $= (+49.05 \text{ m/s})(5.00 \text{ s}) + \frac{1}{2}(-9.81 \text{ m/s}^2)(5.00 \text{ s})^2$ $= +245.3 \text{ m} + (-122.6 \text{ m})$ $= +123 \text{ m}$
Paraphrase	The maximum displacement of the object is 123 m [upward].

Self-Check

SC 7. Go to page 63 of your textbook and answer question 10 of "1.6 Check and Reflect." (**Hint:** Problems like this are most easily solved by taking the downward half of the projectile's path.)

Check your work with the answer in the appendix.

Module 1: Lesson 5 Assignment

Remember to submit the answer to TR 4 to your teacher as part of your Lesson 5 Assignment in the Module 1 Assignment Booklet.

Try This

TR 4. A water balloon is dropped on some unsuspecting sunbathers from a stationary hot air balloon. The water balloon is 353 m above the beach. If the water balloon accelerates downwards at 9.81 m/s^2, how long will it take to hit the beach?

Read

How do these formulas tie into the graphs that you studied in the first four lessons? Read from the middle of page 61 to the bottom of page 62 of your textbook.

Self-Check

SC 8. Go to page 62 of your textbook and answer questions (a) and (b) of “Concept Check.”

Check your work with the answer in the appendix.

Reflect and Connect

There are many cases of airplane crashes related to runway length. For example, in August 2006, Comair Flight 5191 crashed at the airport at Lexington, Kentucky, killing 49 of the 50 people onboard. The plane ended up nearly a kilometre from the end of the runway when the pilot attempted to take off from a runway that was too short. Why do such accidents occur? Using kinematics principles, you are able to explore what variables would need to be known and how they would be used to determine a safe runway length. Would it be the same for both the takeoff and landing of a specific type and size of plane?

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Discuss

Believe it or not, airports and runways are a relatively new technology. Less than 100 years ago, all a plane could land on was a long, semi-flat grass field. (This style of runway can still be found today in rural and remote areas.) However, the increased air travel that emerged after World War I led to the construction of paved runways. This meant that planes had to approach the runway from a specific direction and elevation, which led to such things as visual aids to help pilots land safely. Following World War II, airports became much more sophisticated, with terminals and multiple runways. In 1960, airport construction boomed. At the same time, commercial air travel became commonplace. Runways were extended to a length of 3 km to accommodate larger, heavier aircraft.

Using the discussion area, investigate and discuss modern airport and runway design. You may find answers in a library or, if you do an Internet search, by using keywords in combination such as "airport runway design."

D 1. Explain how runway numbers are designated.

D 2. Explain how kinematic principles are applied to the following operational components of

- a modern airport
- air-traffic control
- ground-traffic pattern control
- runway length
- navigational aids
- lighting and signage
- wind indicators
- noise reduction

To find out the causes of the Air France crash or to see pictures, videos, and eye-witness accounts, do an Internet search using keywords such as "Air France crash Pearson video."

Reflect on the Big Picture

In this lesson you learned more about how mathematics can be used to describe motion. You also saw how mathematics and graphical descriptions are related. Understanding how the pictures and the equations support each other will be important as you describe and analyze motion.

To help you reflect on your learning experience in this lesson, complete at least one of these three activities.

- Mathematics, like poetry, packs a massive amount of content into a small package. Understanding how to unpack the content can be difficult sometimes. Create a poem or short story that helps unpack the mathematics into a description of moving objects.

- Create a mind map that links the concepts developed in this lesson with the graphical methods of earlier lessons.

- Write words to a song that put together the concepts of this lesson in a meaningful way.

Store your completed reflection in your Physics 20 course folder.

Module 1: Lesson 5 Assignments

Ensure that you have completed all of the questions in the Lesson 5 Assignment. Contact your teacher to find out how you should submit it.

Add to the KWL chart you worked on in Lessons 1 to 4. Continue to store your chart in your Physics 20 course folder.

Lesson Summary

In this lesson you explored the following essential questions:
- Which equations can help you solve acceleration, velocity, and displacement problems?
- How do you find such equations?

There are six kinematic equations for motion that are derived from graphical analysis. They can be used to solve complex motion problems involving acceleration, velocity, and displacement.

Equation 1

$$\vec{v}_{\text{ave}} = \frac{\Delta\vec{d}}{\Delta t}$$

Equation 2

$$\Delta\vec{d} = \vec{v}_{\text{i}}\Delta t + \tfrac{1}{2}\,\vec{a}(\Delta t)^2$$

Equation 3

$$\Delta\vec{d} = \left(\frac{\vec{v}_{\text{f}} + \vec{v}_{\text{i}}}{2}\right)\Delta t$$

Equation 4

$$\vec{a} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}$$

Equation 5

$$\Delta\vec{d} = \vec{v}_{\text{f}}\Delta t - \tfrac{1}{2}\,\vec{a}(\Delta t)^2$$

Equation 6

$$v_{\text{f}}^2 = v_{\text{i}}^2 + 2a\Delta d$$

Lesson Glossary

kinematics: the study of motion without concern for forces, masses, or energy

Module 1—Motion

Module Summary

When you began this module, you were presented with the following questions:
- What concepts are needed in describing motion?
- How are vectors and scalars used in describing motion?
- How are acceleration, velocity, and displacement used in describing motion?

Each question related to the description of motion. Reflect on the readings, labs, and questions you've been asked to complete in this module. You worked on describing and analyzing the motion of objects such as chuckwagons, cars, and the space shuttle. You learned about the concepts of acceleration, velocity, and displacement and how they relate to the more everyday ideas of speed and distance. One of the major differences you studied was that the former are vector quantities while the latter are scalar quantities.

Module Assessment

Module 1 Project

Submit the KWL chart you have been developing in Lessons 1 through 5 to your teacher for grading. Be sure that each lesson's part of the chart is clearly labelled. Add a short paragraph (200 words or so) that details what you did to learn about the items in the W column of the chart.
This project will be graded out of 28 marks: 5 marks for each lesson and 3 marks for the short paragraph. Each lesson's part of the KWL chart will be scored according to the following guidelines.

Score	Criteria
5 Excellent	The response includes statements covering all parts of the lesson fully using relevant facts and details. Statements made in the response are organized and unambiguous with only minor omissions.
4 Good	The response includes statements covering all parts of the lesson adequately. Statements made in the response are unambiguous and mostly complete.
3 Satisfactory	The response includes statements addressing the basic parts of the lesson. Statements made in the response may be disorganized, ambiguous, or incomplete.
2 Limited	The response includes some statements addressing some of the parts of the lesson. Statements made in the response lack details and clarity.
1 Poor	The response includes a few statements that address some parts of the lesson.
0 Insufficient	The response is incomplete and/or totally off topic.

Module 1 Glossary

accelerated motion: motion of an object that is either increasing or decreasing in speed or changing direction

acceleration: a measure of the rate of change of velocity in relation to time

acceleration-time graph: a graph showing the acceleration of an object at varying times, where time is the independent variable and acceleration is the dependent variable

area: a quantity specifying the size of a region

area relationships: used to find velocity from an acceleration-time graph or displacement from a velocity-time graph

Cartesian method: a system for measuring directions using the x-axis and y-axis

direction: the course that an object follows

displacement: a change in position including both magnitude and direction

distance: the length of the path taken to move from one place to another

instantaneous velocity: the velocity of a object at an instant of time; the slope of the tangent line to the position-time graph for the selected time

kinematics: the study of motion without concern for forces, masses, or energy

navigator method: a system for measuring directions using compass bearings

non-uniform motion: motion that is not at a constant speed in a straight line

one-dimensional motion: motion in a straight line

position: the straight-line distance and direction of an object from the origin

position-time graph: a graph showing the position of an object at varying times, where time is the independent variable and position is the dependent variable

scalar quantity: a measurement that has only magnitude

sign convention: a system for designating directions along a straight line; one direction is positive and the other is negative

slope: a measure of the steepness of a curve

speed: a measure of the distance travelled per unit of time

uniform motion: motion at constant speed in a straight line

vector quantity: a measurement that has a magnitude and a direction

velocity: a measure of the rate of change of position in relation to time

velocity-time graph: a graph showing the velocity of an object at varying times, where time is the independent variable and velocity is the dependent variable

Self-Check Answers

Lesson 1

SC 1.

a. The measurements of time, 8.5 s and 10.0 s, are examples of scalar quantities because these measurements have only magnitude. The measurements of position, 12 m [W] and 20 m [W], are examples of vector quantities because these measurements have both magnitude and direction.

b. The displacement of the chuckwagon is from 8.5 s to 10.0 s is 8 m [W]. This value represents the change in the position during this time.

c.

Given

Note that east is considered to be the positive direction, while west is negative.

$$\begin{aligned}\vec{d}_i &= 12\text{ m [W]}\\ &= -12\text{ m}\end{aligned}$$

$$\begin{aligned}\vec{d}_f &= 20\text{ m [W]}\\ &= -20\text{ m}\end{aligned}$$

Required

displacement, $\overrightarrow{\Delta d}$

Analysis and Solution

$$\begin{aligned}\overrightarrow{\Delta d} &= \vec{d}_f - \vec{d}_i\\ &= (-20\text{ m}) - (-12\text{ m})\\ &= -8\text{ m}\end{aligned}$$

The answer is negative, so the direction is west.

Paraphrase

The displacement of the chuckwagon is 8 m west of the initial position.

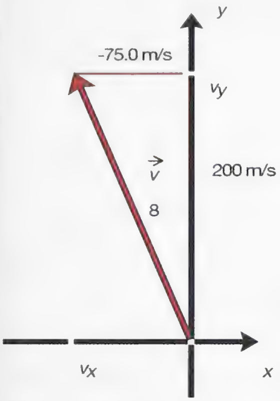
SC 2.

a. The measurement of speed, 9.0 m/s, is a scalar quantity because this measurement has only magnitude. The measurement of velocity, 12.5 m/s [W], is a vector quantity because this measurement has both magnitude and direction.

b. The speed of the chuckwagon can be described as $v = 9.0$ m/s. The velocity of the chuckwagon can be described as $\vec{v} = 12.5$ m/s [W], or $\vec{v} = -12.5$ m/s.

SC 3. This direction could also be described as 59° W of N or as 31° N of W.

SC 4.



$v_x = -75.0$ m/s, $v_y = +200$ m/s

Required

the magnitude and polar positive direction of the vector, $\vec{v}$

Analysis and Solution

Use the theorem of Pythagoras to calculate the magnitude of the vector and the tangent function to calculate the direction. The fact that the x component is negative and the y component is positive indicates that the vector will be in the second quadrant. Therefore, add 90° to the angle found by calculation to give the polar positive angle.

$$v = \sqrt{v_x^2 + v_y^2}$$
$$v = \sqrt{(75.0 \text{ m/s})^2 + (200 \text{ m/s})^2}$$
$$v = 214 \text{ m/s}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$\tan\theta = \frac{75.0 \text{ m/s}}{200 \text{ m/s}}$$

$$\tan\theta = 0.3750$$

$$\theta = \tan^{-1}(0.3750)$$

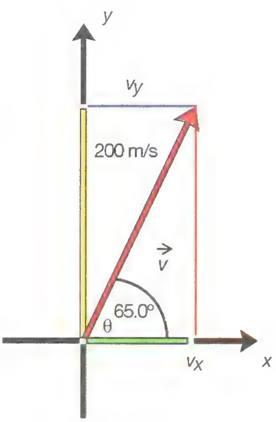
$$\theta = 20.6^\circ$$

The polar positive angle is found by: 90.0° + 20.6° = 110.6°

Paraphrase

The magnitude and polar positive direction of the vector, $\vec{v}$, is 214 m/s [110.6°].

SC 5.



Given

The vector is 126 m/s [65.0° N of E].

Required

to find the x and y components (v_x) and (v_y)

Analysis and Solution

Use the cos function to find the v_x and the sin function to find the v_y.

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$$
$$\text{adjacent} = (\cos\theta)(\text{hypotenuse})$$
$$v_x = (\cos 65.0^\circ)(126 \text{ m/s})$$
$$v_x = 53.2 \text{ m/s}$$

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$$
$$\text{opposite} = (\sin\theta)(\text{hypotenuse})$$
$$v_y = (\sin 65.0^\circ)(126 \text{ m/s})$$
$$v_y = 114 \text{ m/s}$$

Paraphrase

The x and y components are 53.2 m/s and 114 m/s, respectively.

Lesson 2

SC 1. This is a sample answer. Other differences may be noted. Distance can follow a changing path, but displacement follows a straight line. When displacement is written, direction is part of it, but none need be given for distance.

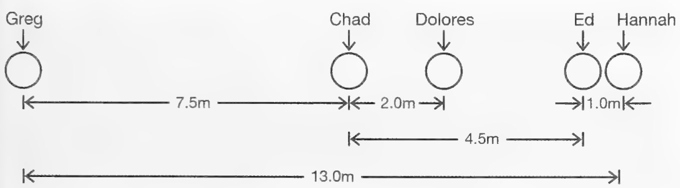
SC 2. The distance changed significantly while the displacement remains constant. This is because displacement is the straight-line distance from the starting position to the finishing position.

SC 3. Distance is the length of the path needed to go from one place to another. It has no direction attached. The symbol for distance is Δd. Displacement is a measure of the magnitude of a change in position, and it includes an expression of direction. The symbol for displacement is $\Delta\vec{d}$.

SC 4. A reference point is necessary for measurements such as position, distance, and displacement because they are all measured relative to some reference point.

SC 5.

4. (a)–(d)



Analysis and Solution

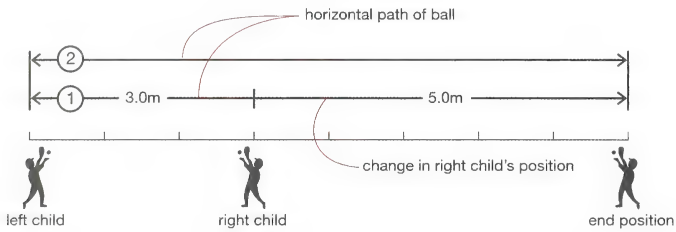
4. (e) The reference point is Greg. Let to the right be positive direction.

$$\begin{aligned}\Delta\vec{d}_{\text{teacher}} &= (+7.5\ \text{m}) + (+4.5\ \text{m}) + (+1.0\ \text{m}) \\ &= +13.0\ \text{m}\end{aligned}$$

Paraphrase

The displacement of the teacher is 13.0 m [right].

SC 6.



Required

- the horizontal distance the ball travels (Δd)
- the displacement of the ball ($\Delta\vec{d}$)

Analysis and Solution

Let the right be the positive direction. In calculating distance, direction is not taken into account. However, in calculating displacement, it is.

$$\begin{aligned}\Delta d &= 3.0\ \text{m} + 3.0\ \text{m} + 5.0\ \text{m} \\ &= 11.0\ \text{m}\end{aligned}$$

$$\begin{aligned}\Delta\vec{d} &= (-3.0\ \text{m}) + (+3.0\ \text{m}) + (+5.0\ \text{m}) \\ &= +5.0\ \text{m}\end{aligned}$$

Paraphrase

The horizontal distance the ball travels is 11.0 m.
The displacement of the ball is 5.0 m [right] of its initial position.

SC 7. Velocity has a direction, and speed doesn't. Velocity is displacement divided by time, and speed is distance divided by time. Speed is a larger number than velocity.

SC 8.

Given

scale is 5.0 m [S] = 6.0 cm

Required

the length of a scale vector diagram of 20 m [S]

Analysis and Solution

The length of the vector scale diagram will be proportional to the scale. Set up a proportionality ratio such that the m units cancel and the cm remain.

$$20\text{ m}\times\frac{6.0\text{ cm}}{5.0\text{ m}}=24\text{ cm}$$

Paraphrase

The length of the scale vector diagram is 24 cm.

SC 9.

Given

Initial segment of journey is 500 km [N].
Final displacement is 50 km [N].
Three southward segments are each 50 km longer than the previous one.

Required

the length of each displacement south

Analysis and Solution

Choose north as the positive direction.
Let the first displacement be $\Delta\vec{d}$ km [S]. Then the next one is ($\Delta\vec{d}$ + 50) km [S], and the third displacement is ($\Delta\vec{d}$ + 100) km [S]. The sum of the displacements is given by the following equation:

$$+500-\Delta\vec{d}-\left(\Delta\vec{d}+50\right)-\left(\Delta\vec{d}+100\right)=50$$

Solve the equation.

$$\begin{aligned} +500-\Delta\vec{d}-\Delta\vec{d}-50-\Delta\vec{d}-100 &= 50 \\ 350-3\Delta\vec{d} &= 50 \\ -3\Delta\vec{d} &= -300 \\ 3\Delta\vec{d} &= 300 \\ \Delta\vec{d} &= 100 \end{aligned}$$

Paraphrase

The three displacements are 100 km [S], 150 km [S], and 200 km [S].

SC 10.

Given

initial height = 10.0 m
height of bounces = 8.0 m, 4.0 m, and 2.0 m

Required

- the distance the ball travels (Δd)
- the displacement of the ball ($\Delta\vec{d}$)

Analysis and Solution

Choose the positive direction to be upwards. Distance is the sum of the magnitudes of the downward journeys and upward bounces. Displacement is measured from the initial position to the final position.

$$\begin{aligned} \Delta d &= 10.0 \text{ m}+8.0 \text{ m}+8.0 \text{ m}+4.0 \text{ m}+4.0 \text{ m}+2.0 \text{ m} \\ &= 36.0 \text{ m} \end{aligned}$$

$$\begin{aligned} \Delta\vec{d} &= (-10.0 \text{ m})+(+2.0 \text{ m}) \\ &= -8.0 \text{ m} \end{aligned}$$

Paraphrase

The distance the ball travels is 36.0 m.
The displacement of the ball is 8.0 m [downwards].

SC 11. The speed decreases instead of increasing.

SC 12. The direction of the motion changes, but the speed remains the same.

SC 13.

Given

All directions are forward.

(a) $\vec{v}_i = 0.00$ m/s $\vec{v}_f = 2.80$ m/s $t_i = 0.00$ s $t_f = 0.50$ s

(b) $\vec{v}_i = 2.80$ m/s $\vec{v}_f = 9.80$ m/s $t_i = 0.50$ s $t_f = 3.00$ s

(c) $\vec{v}_i = 11.30$ m/s $\vec{v}_f = 11.60$ m/s $t_i = 5.00$ s $t_f = 6.00$ s

Required

(a) $\vec{a}_{ave}$ from 0.00 s to 0.50 s

(b) $\vec{a}_{ave}$ from 0.50 s to 3.00 s

(c) $\vec{a}_{ave}$ from 5.00 s to 6.00 s

(d) What is happening to $\vec{a}$ and $\vec{v}$ over 6.00 s?

Analysis and Solution

Choose the forward direction to be positive.

(a)
$$\begin{aligned}\vec{a}_{ave} &= \frac{\Delta \vec{v}}{\Delta t} \\ &= \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i} \\ &= \frac{2.80\text{ m/s} - 0.00\text{ m/s}}{0.50\text{ s} - 0.00\text{ s}} \\ &= 5.6\text{ m/s}^2\end{aligned}$$

(b)
$$\begin{aligned}\vec{a}_{ave} &= \frac{\Delta \vec{v}}{\Delta t} \\ &= \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i} \\ &= \frac{9.80\text{ m/s} - 2.80\text{ m/s}}{3.00\text{ s} - 0.50\text{ s}} \\ &= 2.8\text{ m/s}^2\end{aligned}$$

$$\begin{aligned}(c)\ \vec{a}_{ave} &= \frac{\Delta \vec{v}}{\Delta t} \\ &= \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i} \\ &= \frac{11.60\ \text{m/s} - 11.30\ \text{m/s}}{6.00\ \text{s} - 5.00\ \text{s}} \\ &= 0.30\ \text{m/s}^2\end{aligned}$$

Paraphrase

(a) The acceleration during the first 0.50 s is 5.6 m/s^2 [forward].

(b) The acceleration during the 0.50 s to 3.00 s period is 2.8 m/s^2 [forward].

(c) The acceleration during the 5.00 s to 6.00 s period is 0.30 m/s^2 [forward].

(d) The acceleration decreases, and the velocity increases.

Lesson 3

SC 1. The graph line is a two-dimensional diagram, moving up and down as well as to the right. Taylor moved back and forth on the same street, which is a one-dimensional path.

SC 2. The slope of the graph line in a position-time graph gives the average velocity during that time period.

SC 3. Two objects can have the same speed but have different velocities if they are travelling in different directions.

SC 4. The sign of the velocity during that time period could change from positive to negative, or vice-versa.

SC 5.

Part A

$$\begin{aligned}\text{slope} &= \frac{\text{risc}}{\text{run}} \\ &= \frac{16.0\ \text{m} - 0.0\ \text{m}}{4.0\ \text{s} - 0.0\ \text{s}} \\ &= 4.0\ \text{m/s}\end{aligned}$$

The motion in part A is uniform motion at 4.0 m/s [W].

Part B

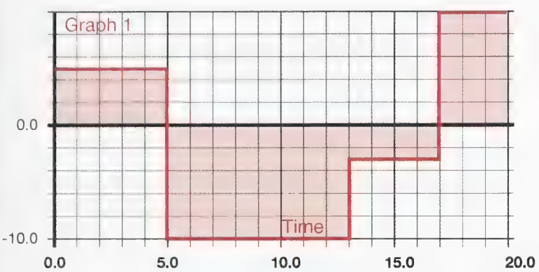
The slope of part B is zero, so during part B the motion is stopped.

Part C

$$\begin{aligned}\text{slope} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{0.0\ \text{m} - 16\ \text{m}}{20\ \text{s} - 12\ \text{s}} \\ &= -2.0\ \text{m/s}\end{aligned}$$

The motion in part C is uniform motion at –2.0 m/s [W] or 2.0 m/s [E].

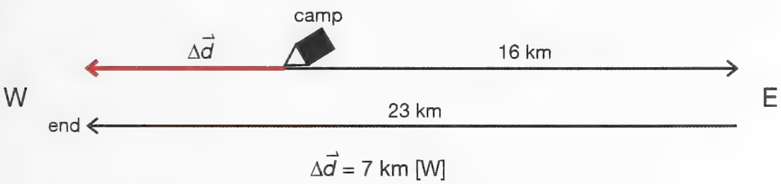
SC 6.



Total displacement (integral) as indicated in the simulation "output": –43.0 m

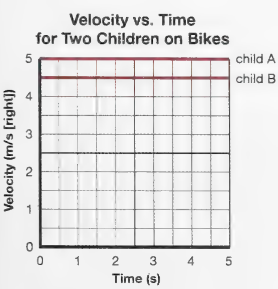
SC 7. (i) D (ii) C (iii) A (iv) B

SC 8.



The camper's final position is 7 km [W] of the camp.

SC 9.



The area under a velocity vs. time graph line is the displacement. The difference in areas for the graphs of the two children is the difference in their displacements.

$$\begin{aligned}\text{distance A is from B} &= \text{Area}_A - \text{Area}_B \\ &= (5.0 \text{ m/s})(5.0 \text{ s}) - (4.5 \text{ m/s})(5.0 \text{ s}) \\ &= 2.5 \text{ m}\end{aligned}$$

Child A is 2.5 m farther from the point of origin than child B.

SC 10.

Given

$\Delta\vec{d}_{\text{friend}} = 5.0 \text{ m } [\text{N}] \quad \vec{v}_{\text{friend}} = 2.0 \text{ m/s } [\text{N}]$

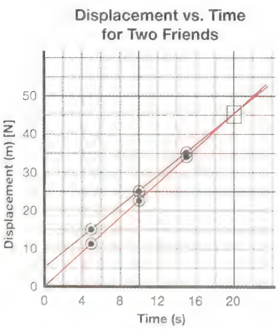
$\vec{v}_{\text{self}} = 2.25 \text{m/s} [\text{N}]$

Required

the time to catch up to your friend, and your displacement when you catch up to your friend

Analysis and Solution

Make a table of values to draw a displacement-time graph for the motion of your friend and yourself. The motions will be uniform, so the graphs will be straight lines. Observe the graph to see when the difference in displacements of your friend and yourself is 0.0 m.



t (s)	$\Delta\vec{d}_f$ (m)	$\Delta\vec{d}_y$ (m)
0	5	0
5	15	11.25
10	25	22.5
115	35	33.75

From the graph, the moment when the difference in displacements of your friend and yourself is 0.0 m occurs at 20 s. Reading the graph at that point indicates your displacement is 45 m.

Paraphrase

The time it takes you to catch up to your friend is 20 s, and your displacement when you catch up to your friend is 45 m [N].

SC 11. The graph line with the greatest slope is the graph line of the winner. Another way of looking at it is the graph line that reaches the 100 m position in the shortest time is the graph line of the winner.

SC 12.

Given

three position-time graphs

Required

to find the velocity of each object from the graphs

Analysis and Solution

Find the slope of the velocity-time graph for the time interval given. The slope will be equal to the velocity of the object in that interval of time.

(a) The positive direction of the position is forward.

$$\begin{aligned}\text{slope} &= \frac{\text{rise}}{\text{run}}\\ \text{slope} &= \frac{-10\text{ m}}{10\text{ s}}\\ \text{slope} &= -1.0\text{ m/s}\end{aligned}$$

(b) The positive direction of the position is forward. The time of 10 minutes will be converted to seconds using a ratio set up, so the minutes units cancel.

$$10 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} = 600 \text{ s}$$

$$\text{slope} = \frac{\text{rise}}{\text{run}}$$
$$\text{slope} = \frac{-20 \text{ m}}{600 \text{ s}}$$
$$\text{slope} = -0.033 \text{ m/s}$$

(c) The positive direction of the position is forward.

$$\text{slope} = \frac{\text{rise}}{\text{run}}$$
$$\text{slope} = \frac{25 \text{ m}}{15 \text{ s}}$$
$$\text{slope} = 1.7 \text{ m/s}$$

Paraphrase

The velocity in each case is

(a) 1.0 m/s [backward]
(b) 0.033 m/s [left]
(c) 1.7 m/s [forward]

SC 13.

Given

$v_{ave} = 30.0 \text{ m/s } [\text{W}]$ $\Delta t = 15.0 \text{ min}$

Required

the vehicle's displacement ($\Delta\vec{d}$)

Analysis and Solution

The solution can be found algebraically by rearranging the average velocity formula. The time of 15.0 minutes will be converted to seconds using a ratio set up so that the minutes units cancel.

$$15.0\text{ min} \times \frac{60\text{ s}}{1\text{ min}} = 900\text{ s}$$

$$\vec{v}_{ave} = \frac{\Delta\vec{d}}{\Delta t}$$

$$\begin{aligned}\Delta\vec{d} &= \vec{v}_{ave}\Delta t \\ &= (30.0\text{ m/s})(900\text{ s}) \\ &= 2.700 \times 104\text{ m} \times \frac{1\text{ km}}{1\,000\text{ m}} \\ &= 27.0\text{ km}\end{aligned}$$

The positive value means the direction is west.

Paraphrase

The vehicle's displacement is 27.0 km [W].

SC 14.

Given

position-time graph

Required

the average speed (v_{ave}), average velocity ($\vec{v}_{ave}$), and net displacement ($\Delta\vec{d}$)

Analysis and Solution

The positive direction is toward the right.

$$\begin{aligned}d_{total} &= (25.0\text{ m} - 0.0\text{ m}) + |(-25.0\text{ m}) - (+25.0\text{ m})| \\ &= 25.0\text{ m} + 50.0\text{ m} \\ &= 75.0\text{ m}\end{aligned}$$

$$\begin{aligned}v_{ave} &= \frac{\Delta d}{\Delta t} \\ &= \frac{75.0\text{ m}}{20.0\text{ s}} \\ &= 3.75\text{ m/s}\end{aligned}$$

$$\begin{aligned}\Delta\vec{d} &= \vec{d}_f - \vec{d}_i \\ &= (-25.0\text{ m}) - (0.0\text{ m}) \\ &= -25.0\text{ m}\end{aligned}$$

The negative value indicates the direction is left.

$$\begin{aligned}\vec{v}_{ave} &= \frac{\Delta\vec{d}}{\Delta t}\\ &= \frac{-25.0\text{ m}}{20.0\text{ s}}\\ &= -1.25\text{ m/s}\end{aligned}$$

The negative value indicates the direction is left.

Paraphrase

The average speed is 3.75 m/s. The average velocity is 1.25 m/s [left], and the net displacement is 25.0 m [left].

SC 15.

Given

velocity-time graph

Required

the distance the elk will travel (Δd) in 30 min

Analysis and Solution

The area between a velocity-time graph and the time axis for a given interval of time is equal to the displacement of the object in that interval of time. Find the area under the graph line and the value without the direction will equal the distance. The time of 30 min = 0.50 h.

$$\begin{aligned}A &= l \text{ x } w\\ &= (35\text{ km/h})(0.50\text{ h})\\ &= 18\text{ km, corrected to 2 significant digits}\end{aligned}$$

Paraphrase

The elk will travel 18 km.

Lesson 4

SC 1.

a. The position-time graph line was a curved diagonal line with a gradually increasing slope.
b. The velocity-time graph was a straight diagonal line going from lower left to upper right.
c. The acceleration-time graph was a horizontal line

SC 2. The slope of a velocity-time graph of uniform motion is zero (flat). The slope of a velocity-time graph of non-uniform motion has a non-zero value (diagonal line).

SC 3. The object is moving to the left with ever increasing speed.

SC 4. The slope of the tangent to a curved position-time graph gives the velocity at that exact time, called the **instantaneous velocity**.

instantaneous velocity: the velocity of an object at an instant of time; the slope of the tangent line to the position-time graph for the selected time

SC 5. (i) A (ii) B (iii) C (iv) D

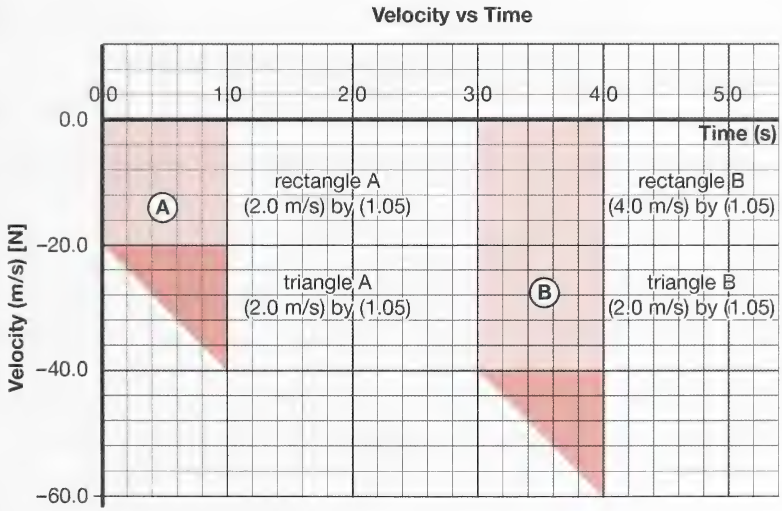
SC 6. An object could have a negative acceleration and not be slowing down if the direction of the velocity was also negative.

SC 7.

a. From a velocity-time graph, you get the displacement by taking the area under the graph line.

b. From a velocity-time graph, you get the acceleration by taking the slope of the graph line.

SC 8.



SC 9.

Analysis and Solution

Choose east to be the positive direction. The displacement is equal to the area under the Velocity vs. Time-graph line. The area can be divided into a rectangle and a triangle.

$A = lw + \frac{1}{2}ab$

$= (10.0\text{ s})(5.0\text{ m/s}) + \frac{1}{2}(10.0\text{ m/s})(5.0\text{ s})$

$= 50\text{ m} + 25\text{ m}$

$= 75\text{ m}$ The positive value indicates the direction is east.

Paraphrase

The displacement from the graph is 75 m [E].

SC 10.

Analysis and Solution

Choose the positive direction to be toward the right. The slope of the Velocity vs. Time-graph is equal to the acceleration.

$$\begin{aligned} \text{slope} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{10.0 \text{ m/s}}{30.0 \text{ s}} \\ &= 0.333 \text{ m/s}^2 \end{aligned}$$

The positive value indicates the acceleration is directed to the right.

Paraphrase

The acceleration from the graph is 0.333 m/s^2 [right].

Lesson 5

SC 1.

Given

$$\begin{aligned} \vec{v}_i &= 14.0 \text{ m/s} \\ \vec{v}_f &= 0.0 \text{ m/s} \\ \Delta t &= 2.80 \text{ s} \end{aligned}$$

Required

the skidding distance ($\vec{d}$)

Analysis and Solution

Distance is a scalar quantity, so direction is not a factor. The magnitude of displacement equals distance. Therefore, the equation that uses all the variables is

$$\Delta\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right)\Delta t$$

$$\begin{aligned}\Delta\vec{d} &= \left(\frac{0.0 \text{ m/s} + 14.0 \text{ m/s}}{2}\right)2.80 \text{ s} \\ &= 19.6 \text{ m}\end{aligned}$$

Paraphrase

The skidding distance is 19.6 m.

SC 2.

Given

$\vec{v} = 20$ km/h [N]
$\vec{a} = 1.5$ m/s^2 [N]
$\Delta t = 9.3$ s

Required

the maximum velocity of the elk ($\vec{v}_f$)

Analysis

Choose north to be the positive direction. Convert the initial velocity to m/s. The final velocity will have to be converted back to km/h.

Use the equation $\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$, and manipulate it to isolate $\vec{v}_f$.

Solution

$$\begin{aligned}\vec{v}_i &= 20\frac{\text{km}}{\text{h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}} \\ &= 5.56 \text{ m/s}\end{aligned}$$

$$\begin{aligned}\vec{a} &= \frac{\vec{v}_f - \vec{v}_i}{\Delta t} \\ \vec{a}\Delta t &= \vec{v}_f - \vec{v}_i \\ \vec{v}_f &= \vec{v}_i + \vec{a}\Delta t_i\end{aligned}$$

$= (5.56 \text{ m/s}) + (1.5 \text{ m/s}^2)(9.3 \text{ s})$
$= 5.56 \text{ m/s} + 13.95 \text{ m/s}$

$$= 19.5 \text{ m/s}$$
$$= 19.5 \text{ m/s} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{3600 \text{ s}}{1 \text{ h}}$$
$$= +70 \text{ km/h}$$

Paraphrase

The maximum velocity of the elk is 70 km/h [N].

SC 3.

Given

$\vec{v}_i$ = 100 km/h
$\vec{a}$ = –0.80 m/s^2
Δt = 1.0 min = 60 s

Required

the distance the motorcycle travelled (Δd)

Analysis and Solution

The equation that uses the variables is $\Delta \vec{d} = \vec{v}_i \Delta t + 1/2\, \vec{a} (\Delta t)^2$. Distance is not a vector quantity, so the final answer will not require direction. Convert the initial velocity to m/s.

$$\vec{v}_i = 100 \text{ km/h} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}}$$
$$= 27.78 \text{ m/s}$$

$$\Delta d = (+27.78 \text{ m/s})(60 \text{ s}) + \frac{1}{2}\left(-0.80 \text{ m/s}^2\right)(60 \text{ s})^2$$
$$= 1667 \text{ m} - 1440 \text{ m}$$
$$= 227 \text{ m}$$
$$= 2.3 \times 10^2 \text{ m, correct to 2 significant digits}$$

Paraphrase

The distance the motorcycle travelled is 2.3 x 10^2 m.

SC 4.

Given

$\vec{v}_i = 70 \text{ m/s [forward]}$
$\vec{v}_f = 0.0 \text{ m/s}$
$\Delta t = 29 \text{ s}$

Required

(a) the acceleration of the jet ($\vec{a}$)
(b) the minimum length of runway (Δd)

Analysis and Solution

(a) The equation that contains all the variables for part (a) is $\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$$\begin{aligned}\vec{a} &= \frac{0 - 70 \text{ m/s}}{29 \text{ s}} \\ &= -2.4 \text{ m/s}^2 \text{ [forward]}\end{aligned}$$

(b) The equation that contains all the variables for part (b) is $v_f^2 = v_i^2 + 2a\Delta d$; however, it will have to be manipulated to isolate Δd.

$$\begin{aligned}\Delta d &= \frac{v_f^2 - v_i^2}{2a} \\ &= \frac{(0)^2 - (70 \text{ m/s})^2}{2(-2.4 \text{ m/s}^2)} \\ &= 1015 \text{ m} \\ &= 1.0 \text{ km}, \quad \text{correct to 2 significant digits}\end{aligned}$$

Paraphrase

The acceleration of the jet is -2.4 m/s^2 [forward], and the minimum length of the runway is 1.0 km.

SC 5. The velocity at the maximum height is 0.00 m/s.

SC 6. The initial velocity for the downward path is 0.00 m/s.

SC 7.

Given

For the last half of the kangaroo's jump:

$\Delta\vec{d} = -3.00 \text{ m}$

$\vec{a} = -9.81 \text{ m/s}^2$

$\vec{v} = 0.0 \text{ m/s}$

Required

the time the red kangaroo is in the air ($2\Delta t$)

Analysis and Solution

Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + 1/2\,\vec{a}(\Delta t)^2$. The initial velocity of the downward path is zero, so the $\vec{v}_i\Delta t$ part of the equation equals zero and the equation becomes $\Delta\vec{d} = 1/2\,\vec{a}(\Delta t)^2$. (That is why it is best to choose the downward path: It eliminates the initial velocity. Otherwise, there are two unknowns and the solution is considerably more difficult.) Manipulate this equation to isolate Δt, using the scalar form of the equation because you cannot divide by a vector.

$$\Delta d = \frac{1}{2}a(\Delta t)^2$$

$$\begin{aligned}\Delta t &= \sqrt{\frac{2\Delta d}{a}}\\ &= \sqrt{\frac{2(-3.0 \text{ m})}{-9.81 \text{ m/s}^2}}\\ &= 0.78 \text{ s}\end{aligned}$$

The time for the up and down path will be $2 \times (0.78 \text{ s})$ or 1.6 s.

Paraphrase

The red kangaroo will remain in the air 1.6 s.

SC 8.

(a) The defining kinematics equation for a ball thrown straight up is $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$.

(b) The expected value of the slope of the velocity-time graph in "Figure 1.67(b)" is -9.81 m/s^2.